TRANSACTIONS

of the

American Society for Steel Treating

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STEEL AND STEEL TREATERS[1]

FROM the other side come reports of increasing difficulty in getting worth-while papers for the Iron and Steel Institute. On this side the American Institute of Mining and Metallurgical Engineers—which once listened to Fritz, Holley, Gayley and Howe—long since loosened its hold on the iron and steel makers. To counterbalance this has been, of course, the remarkable growth of the American Society for Steel Treating.

It might be profitable to speculate on the causes of these fluctuations in society interest. Such societies themselves represent an essential part of the technical and business life of any steel producer. What causes these changes in activity? Certainly a blast furnace or open-hearth or rolling mill superintendent needs to know the latest advances in practice today as well as ten years ago.

Some of the variations may be due to the changing business cycle. Perhaps this is a major cause in England. With dull business, uncertain future and need for economy in expediture, there is small chance to perform the experiments necessary to prove or disprove an idea which has germinated from ripe experience. And without such confirmation the paper that might prove the life of a meeting is never written.

Now and then comes the intimation that the falling off in metallurgical literature has come because the giants have passed on and the younger generation has not yet found itself. That is not the reason. Most men are the product of their times. Given an economic situation that would require the bold design and constructive imagination of John Fritz, and a John Fritz would arise from the ranks of mechanical engineers now engaged in the steel industry.

[1]An editorial from the June 18, 1925, issue of *Iron Age*.

Or, put it another way: We are so used to things big that notable steel plant engineering has become a common-place. Today we accept without comment things that once would have been a seven days' wonder. Another sidelight is the fact that technical organizations have grown so large and are interlocked with others so intimately that achievements now are seldom due to a single man, but to a group.

It is often said that a society stands or falls by the men who are running it. This, again, is only partly true. It is, of course, easy for older organizations to become inbred; to gain a solid conservatism at the expense of a fresh, vivid view. But it would be grossly unfair to charge any of the national organizations with such mismanagement that it affects the individual member's enthusiasm.

No; the main thing for any organization is a vital *idea,* something that touches as many people as possible at the greatest number of points. That, we think, is the reason for the American Society for Steel Treating.

Fifteen years ago a metallurgical microscope was almost a museum curiosity. Not counting the armor plate and ordnance makers, the plants doing any real heat treating could almost be counted on the fingers of one hand. The change in a few short years was strikingly shown at Schenectady last month.

R. B. McColl, manager of the American Locomotive Works, speaking at the Steel Treaters' meeting there said that 45,000 pounds of heat treated steel now goes into every locomotive. At his elbow sat W. S. Bidle, president of the society, a young man at that, who started life selling forged wrought iron locomotive frames!

Multiply this instance by the revolution in nearly everything between automobiles and phonograph needles, and you have the answer. That is the reason why the Steel Treaters have grown so rapidly. That is the reason why the local meetings are well attended every month. And that is the reason why a regional meeting brings out an attendance that many a national gathering would envy.

SPRING SECTIONAL MEETING

THE Spring Sectional Meeting of the Society held at Schenectady, May 28, 29 and 30, proved to be of an unusually interesting and instructive character. Registration of members and

guests took place between 9:30 and 10:00 at the new Hotel Van Curler, and at 10:00 o'colck, the first technical session was held in the Varsity room of the Hotel. V. O. Homerberg, chairman of the Boston chapter of the Society, was chairman of the session. The first paper was presented by P. A. E. Armstrong, Watervliet, N. Y., and was entitled *Stainless Steels and Rustless Irons Correctly Described as Stable Surface Iron.* The author reviewed at considerable length the utilization of stainless steels and stainless iron, pointing out that under many conditions, these materials do not have to be stain-proof in order to be of service under the corrosive action of materials in contact with it. This paper brought out considerable discussion, proving that the subject of stainless steel and iron is of much interest to metallurgists and manufacturers today. The second paper presented by Dr. W. E. Ruder, metallurgist of the Research Laboratory of the General Electric Company, was entitled, *Magnetization and Crystal Orientation.* (Published in this issue of TRANSACTIONS). The third and final paper of this session entitled, *Carburization and Heat Treating of Carburized Objects,* (published in the June issue of TRANSACTIONS), by B. F. Shepherd, metallurgist, Ingersoll-Rand Co., Phillipsburg, N. J., was read in abstract. At 12:00 o'clock, about 200 members and guests drove to the plant of the Ludlum Steel Company at Watervliet, N. Y., where they were the guests of the company. The company had gone to considerable trouble in preparing for the entertainment of their guests, and after serving a complimentary luncheon, conducted the visitors through the entire plant. At 6:30 P. M., a dinner meeting was held in the dining room of the Hotel Van Curler, there being about 250 members and guests present. W. H. Eisenman, national secretary of the A. S. S. T., was toastmaster for this occasion and introduced the various speakers in his own entertaining way. An address of welcome was presented by William Dalton, president of the Schenectady Chamber of Commerce and was responded to by W. S. Bidle, president of the A. S. S. T. Dr. W. R. Whitney, director of the research laboratory of the General Electric Company, gave a talk as did also R. B. McColl, manager of the American Locomotive Works.

Col. T. C. Dickson, commanding officer of the Watertown Arsenal, presented an interesting and capable paper entitled, *Results of Examination of Metals with the X-Ray.* Col. Dickson's paper was followed by a paper entitled, *Manufacture of Guns by*

the Cold Working Process, and was presented by Dr. F. C. Langenberg, director of laboratories, Watertown Arsenal.

FRIDAY, MAY 29

At 9:00 A. M., the members and guests assembled in the lobby of the Hotel Van Curler, from whence they proceeded to the General Electric Company for the purpose of inspecting the plant. The American Locomotive Company likewise had extended an invitation to members to inspect their plant and this was accepted by a number. The morning at the General Electric Company was spent in viewing the various manufacturing departments, principally the foundry, turbine department, welding and electric furnace departments. At 1:30 P. M., a complimentary luncheon was served in the dining room of the Company. Following this luncheon, C. E. Eveleth, manager, General Electric Company, gave a short talk outlining the activities of the Schenectady plant of the company. In the afternoon, an inspection was made of the research laboratory of the company. At 4:00 P. M., a technical session was held in the assembly room of the research laboratory, at which time two papers were presented. A. H. d'Arcambal, metallurgist, Pratt & Whitney Co., Hartford, presided at this session. The first paper entitled, *The High Points in the Manufacture and Working of Steel,* was presented by L. F. Johnson, metallurgist, United Alloy Steel Corp., Canton, Ohio, and the second paper, *Characteristics of Magnet Steels with Special Reference to Radio Requirements,* was presented by R. P. DeVries, metallurgist, Ludlum Steel Co., Watervliet, N. Y. At 6:00 P. M., an informal dinner was held in the Ball Room of the Hotel Van Curler, and at 7:30 P. M., a technical session was held in the Varsity Room. W. E. Ruder presided at this meeting. The first paper entitled, *The Persistence of Austenite at Elevated Temperatures,* was presented by the author, E. C. Bain, metallurgist, Union Carbide & Carbon Research Laboratories, Long Island City, N. Y. The second paper was presented by A. O. Schafer, engineer of tests, Midvale Co., Nicetown, Philadelphia, and was entitled, *Manufacture and Heat Treatment of Large Forgings,* and the third paper entitled, *Determination of Heat Treatment Costs and Furnace Efficiencies,* was presented by C. L. Ipsen, of the industrial heating department, General Electric Company. Each of these papers proved to be of much interest and brought forth considerable

discussion. Two of these papers are published in this issue of TRANSACTIONS and the third one was published in the June issue of TRANSACTIONS.

LAKE GEORGE TRIP

About 30 members took advantage of the trip to Lake George which had been arranged for by the members of the Schenectady chapter of the Society. At 9:30 Saturday morning, these members proceeded by automobile to Lake George, passing through Saratoga Springs and Glen Falls. After arriving at Lake George, luncheon was served and the beauties of the Adirondacks were observed.

It is interesting to observe the success of these sectional meetings, and in this respect, we are quoting from the June 4th issue of *Iron Age* as follows: "The periodical sectional meetings of the American Society for Steel Treating have become events of influence and importance, not only to the society itself but to the individual members. The board of directors, which inaugurated such meetings about four years ago, have been rewarded beyond their expectations. These gatherings are held in various districts in the winter and spring of each year. Plant visitations and a banquet are regular features.

"The spring meeting this year was held at Schenectady, N. Y., last week, May 28 and 29, and established a record in attendance, in enthusiasm and in general merit. Over 100 members from Cleveland, Pittsburgh, Boston, New York and other chapters were registered. It was the eighth meeting of this type. The first was held in New York in the spring of 1922. The Schenectady chapter was praised for the success of the meeting. Signal co-operation of the General Electric Company and the American Locomotive Company was a feature. The new hotel, the Van Curler, opened only three weeks previously, was the headquarters where most of the technical sessions were held."

Especial credit is due to B. H. Magill, chairman of the Schenectady chapter, and James Taylor, secretary, as well as G. R. Brophy, for their untiring efforts in carrying out plans and arrangements for this meeting.

The Board of Directors of the Society held a meeting in the Hotel Van Curler on Wednesday, May 27th. A report of this meeting follows.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS

HOTEL VAN CURLER, SCHENECTADY, N. Y.

MAY 27, 1925, 2:00 P. M.

Present	
W. S. BIDLE, President	G. K. BURGESS
R. M. BIRD	W. H. EISENMAN
ZAY JEFFRIES	*Absent*
J. F. HARPER	F. G. MCCLEARY
F. G. HUGHES	P. D. MERICA

THE minutes of the meeting of the Board of Directors held in Cincinnati, January 14, 1925, were read and approved.

The secretary then presented a complete report of the facilities of various cities to provide accommodations for the 1926 convention and exposition. After giving the matter thorough consideration, it was moved by Dr. Jeffries, seconded by Dr. Burgess, and unanimously carried that Chicago be selected as the convention city for 1926, providing satisfactory arrangements can be made.

A communication was received from a chapter requesting the Board to give consideration to granting free of charge all the data sheets issued up to date to all new members. The Board took into consideration the cost of the data sheets to date ($7,502.71); the large turnover in the membership of the Society; that due to the fact there is a great variety of members, all would not be interested in all of the back data sheets; and further, a disinclination to approve the offering of any inducements in order to obtain members; consequently it was moved by Mr. Bird, seconded by Mr. Hughes, and unanimously carried, that there should be no change from the present ruling of the Board as published in TRANSACTIONS, Vol. VI, page 11, providing as follows:

> "After July 1, 1924, no further free distribution of back data sheets will be made, but the newly elected members shall be privileged to purchase such previously published sheets as he may desire at the rate of five cents (5c) per sheet. It is understood, however, that the new member receives free of charge the data sheets issued during the time covered by his membership dues."

Mr. Harper, chairman of the Recommended Practice Committee, presented a report of the activities of this committee. Upon motion properly made and seconded the report was approved.

Mr. Harper then presented letters from the S. A. E. and A. S. T. M., requesting the A. S. S. T. to cooperate with them in the re-

constituting of the former joint committeee of the A. S. T. M., S. A. E., and the A. S. S. T., to consider standardization of definitions of terms relating to heat treatment. After thorough discussion of the matter, it was moved by Dr. Burgess, seconded by Dr. Jeffries, and unanimously carried that the Board should go on record in favor of endeavoring to bring together the three societies on the subject of heat treatment definitions, and that, if possible, a meeting should be held in Atlantic City in June, during the A. S. T. M. annual meeting. It was moved by Dr. Burgess, seconded by Mr. Hughes, and unanimously carried, that the president should appoint three members to represent the A. S. S. T. at this conference.

A communication was read from Mr. Jewett, chairman of the Division of Engineering and Industrial Research of the National Research Council, stating that it had been suggested that the work of the committeee on Hardness Testing of Metals, which had previously worked under the National Research Council could probably best be undertaken by the A. S. S. T.

Upon motion properly made, seconded and carried, this committee on Hardness Testing was accepted as an A. S. S. T. committee.

Dr. Jeffries, treasurer, presented a financial statement, copy of which was published in the May issue of TRANSACTIONS, page 568. This report was approved.

It was moved, seconded and unanimously carried, that the treasurer be authorized to invest $10,000.00 of the Society's finances in Cleveland Trust Company's guaranteed bonds.

On motion properly made, seconded and carried, the meeting adjourned at 6:00 P. M.

HOTEL ACCOMMODATIONS FOR THE CLEVELAND CONVENTION

THE following list of Cleveland hotels is published in order to give members and guests an opportunity to make their selections in obtaining hotel accommodations during the time of the Seventh Annual Convention and Exposition of the American Society for Steel Treating, to be held in Cleveland the week of September 14, 1925.

The Hotel Cleveland will be the headquarters of the Society. All of the listed hotels are in close proximity to the Public Audi-

1. Hotel Cleveland
2. Hollenden Hotel
3. Statler Hotel
4. Winton Hotel
5. Olmsted Hotel
6. Colonial Hotel
7. Murphy's Hotel
8. New Amsterdam Hotel
9. Euclid Hotel
10. Public Auditorium
11. New Public Library
12. Union Trust Building
13. Post-Office
16. Stillman Theater
17. County Court House
18. City Hall
19. Hanna Theater
20. Y. W. C. A.
21. Y. M. C. A.

Map of Business Section of Cleveland Showing Location of Hotels, Theatres, etc.

torium where the exposition will be held. In fact, all of these hotels are within walking distance of the Public Auditorium.

In making reservation, members are requested to communicate directly with the manager of the hotel at which he wishes to be located, stating time of arrival, kind of accommodation desired, and the price he wishes to pay. It is also suggested that the hotel management be requested to acknowledge receipt of each reservation.

List of Cleveland Hotels

HOTEL CLEVELAND
(F. L. Bonneville, Asst. Mgr.)
CONVENTION HEADQUARTERS
(All rooms with bath)

Single rooms	$3.00,	$3.50,	$4.00,	$4.50,	$5.00,	$6.00,	$ 7.00 and	$ 8.00
Double rooms	5.00,	5.50,	6.00,	6.50,	7.00,	8.00,	9.00 and	10.00
Twin beds	7.00,	8.00,	9.00,	10.00,	12.00.			

Suites—one person.....$12.00 and up Suites—three persons...$20.00 and up
Suites—two persons .... 14.00 and up Suites—four persons ... 22.00 and up

WINTON HOTEL
(R. M. Lewis, Asst. Mgr.)
(All rooms with bath)

Single rooms	$ 3.00 to $ 5.00
Double rooms	5.00 to 8.00
Double rooms—twin beds	7.00 to 10.00
Suites	15.00 to 18.00

STATLER HOTEL
(H. F. Dugan, Asst. to Mgr.)
(All rooms with bath)

Single rooms—inside or court	$3.00 to $ 4.00
Double rooms—inside or court	4.50 to 6.00
Twin beds—inside or court	5.50 to 7.00
Single rooms—outside	4.00 to 7.00
Double rooms—outside	5.50 to 9.00
Twin beds—outside	7.50 to 12.00

HOLLENDEN HOTEL
(Theo. DeWitt, Mgr.)
(All rooms with bath)

Single rooms—inside	$3.00 to $ 3.50
Double rooms—inside	5.00 to 6.00
Single rooms—outside	4.00 to 6.00
Double rooms—outside	6.00 to 8.00
Double rooms—twin beds	7.00 to 10.00
Suites	10.00 and up

OLMSTED HOTEL
(H. G. Ganson, Mgr.)
(All rooms with bath)

Single rooms with shower or tub	$2.50 to $3.00
Double rooms	4.00 to 6.00
Double rooms—twin beds	6.00
Double rooms—double and single beds	7.50

2. Hollenden Hotel
3. Statler Hotel
4. Winton Hotel
7. Murphy's Hotel
8. New Amsterdam Hotel
11. New Phone Building
12. Union Trust Building
18. City Hall

MURPHY'S HOTEL
(W. L. Murphy)

Single rooms without bath	$2.00
Single rooms with bath	2.50 to $3.00
Double rooms without bath	3.50
Double rooms with bath	5.00
Rooms with 2 double beds with bath	8.00

ULTIMATE SUCCESS

ONE of, if not the most startling, disclosure of modern times is the low rate of compensation given for technical training and technical achievement. The first reaction to the young man who contemplates a course of technical training is the comparatively low compensation for technical men as compared with the remuneration for those in the other branches of commerce and industry, and he quite naturally asks, "Will it pay?" Are we able to point out that it does pay, will pay, or should pay? All of us will admit that it should pay, but does it? If not, why doesn't it? The one and only reason why technical achievements are not, as a rule, rewarded in a monetary way is that the value and necessity of technical skill has never been thoroughly sold to the world at large. Technical achievements have been looked upon with awe and admiration but they have never been thought of as a necessity, without which there could be no progress.

Truly, it is not quite in accord with the ideal existence to think of success as a reward in dollars and cents. But by the world's present standards, success means money, and the world's expression of appreciation for something well done is a reward in money. The relative importance of an individual in the success of an undertaking or industry is thought to be in direct proportion with the monetary compensation to each individual of the organization. If such is the case, then the technical men, the research men, and the heat-treaters contribute very slightly to the success of any undertaking. How wrong the whole scheme is yet no one can be blamed for such a condition of affairs more than the technical men, the research men, and the heat-treaters themselves. They have never sold their worth. They have been content with personal achievements, and have been bound by what they term "ethics" and what the world at large terms "rot." It certainly is high time that the technical men, the men who are alone responsible for industrial progress, stepped out in front and sold themselves and their worth. This selling sounds

like a monstrous undertaking, but in reality it is simple in comparison with marketing of other sorts. It should be worked out in such a way that the present scheme of things will apparently remain uninterrupted with the possible readjustment in the ranking scale of relative importance.

Suppose we take, for example, any manufacturing establishment where steel is either machined or fabricated, and passing over the ranking personnel we come down to the one in the organization who, through a series of research and tests, has devised a series of heating and cooling treatments for various items used, so that a great saving in both material and production cost has been perfected and this company's product is most capable of meeting the use and abuse to which it may be subjected. Does this particular concern herald to the world that its success was made possible by a heat-treater, a technical man, who, fitted by years of training and study, worked out the processes to make their product superior? Does this establishment compensate that particular heat-treater in accord with the saving in material cost and marketing possibilities for which he has been wholly responsible? It does neither and the reason it does neither is because the heat-treater has never sold his worth to the management. The executives are of the impression that any heat-treater could have done as well or possibly better, in its opinion the heat-treater is of no more importance than any one of the crafts or trades entering into the scheme of manufacturing. He is only a hired hand and should be remembered as such. The chief reason for this attitude is that those in the organization, other than those familiar with heat treating, are wholly ignorant of the importance and possibilities of heat treating.

Salesmanship, no matter whether it be selling shoe laces, railroad locomotives, or personal skill, depends upon ability to describe that which is to be sold and weave in along with this explanation the network of argument, showing why the buyer should purchase. The success in selling is directly dependent upon the ability to convey the possession of thorough knowledge of the commodity to be sold, as well as to impress upon the purchaser his necessity for the commodity. The heat-treater should first of all sell heat-treating and then follow that by selling himself as a heat-treater and not as a hired man.

Let us take a case and work it out. Say we are making

gears at this particular plant; gears which are to be subjected to unusually severe treatment. The report comes in that the gears made under the old scheme of things are failing; the teeth break off, and the gears must be replaced often. Somewhere the management has learned of heat-treatment, so they call in a metallurgist who goes after the problem and finds that by using steel of another chemical analysis and subjecting it to the proper heat treatment, gears may be made which are far lighter than the old ones and will stand more than the abuse required of them without showing perceptible wear. The system is adopted and the metallurgist is added to the pay-roll to carry out this new plan. Because of the new process the gears soon are known as superior to the competitor's and the business increases until the plant is operating on twice the production basis of the old gear shop, the management is pleased and while they attribute their new success to the new plan, they have no idea of permitting the one who made all this possible to share in the increased profit. Instead they threaten him with replacement if he suggests an increase in compensation because he has never taken the trouble to sell himself. What this metallurgist should have done is, rather than be content with the self-satisfaction of success, he should have taken the subject before the management and proved his worth, proved exactly what he had done and what might be possible in the future. Managers are most willing to reward, but they must be shown that the reward is justified. It is up to every one to prove the justification.

In marketing, it is not the idea, it is the way the idea is put over which spells success. Heat-treating is a wonderful idea, its worth has been proven time and time again. Without it many of today's most important mechanical devices would be impossible, yet heat-treating has never been put over and it is up to each and every metallurgist and heat-treater to put the idea over so that its worth will be recognized not only by those familiar with the industry, but by every one. Heat-treating is not a secret process to be practiced behind locked doors. No one can steal it and the more broadcasting that is done about the subject, the more important every one connected with heat-treating becomes. Broken test bars are not for skilled and trained eyes alone. If every man could distinguish at a glance the character of metal by looking at a fracture, and then could suggest a treatment to

better the product, heat-treating would be known as one of the world's most important crafts instead of being, as it is, an almost unknown factor in the scheme of commerce and industry. The doctor in whom we have the most confidence is the one who tells us in terms we may understand that our liver or our stomach is out of fix. The doctor who replies in a long string of medical terms may awe us for a moment, but he never wins our confidence and trust. So let's get down to earth and by a broadcasting of facts known to the few, prove to the masses that in the scheme of things which make for indusrial and commercial proggress heat-treating is the one most important factor. Let's first sell heat-treating to all, then it will be easy for each, metallurgist and heat-treater, to sell himself. We are banded together for the benefit from the exchange of knowledge and ideas, and it is up to us to use this knowledge for the benefit of every one. Our success and standing is entirely dependent upon the regard for us, as a body and as individuals, which is held by the world at large.

If you think these statements may be a bit overdrawn; ask the first person you meet what they know about heat-treating and observe the blank look which will accompany their admission of absolute ignorance of the subject. Yet why shouldn't they know what has made the automobile, the sewing machine, the vacuum cleaner, and hundreds of other commodities with which they are thoroughly familiar, possible? Until that day when every one becomes familiar with heat-treating the heat-treater, regardless of his skill, may expect to be a hired hand of little importance outside of a very small circle of acquaintances. It is up to you, Mr. metallurgist and heat-treater, to sell yourself.

Miles C. Smith, Los Angeles.

THE PERSISTENCE OF AUSTENITE AT ELEVATED TEMPERATURES

By E. C. Bain

Abstract

The stronger atomic bonding between unlike atoms, which is necessary for any solid solution, is offered as the cause for the easier retention of austenite in alloy steels. No separate explanation is required for the two classes of alloying elements.

The temperature to which the preserved austenite must be heated for release or decomposition is charted for a number of common steels and is offered as a measure of its persistence.

The similarity in effect of temperature elevation and cold work upon austenite is shown, and the unusually rapid hardening of austenitic steels by cold work is explained by X-ray evidence of alpha iron production in a form resembling martensite.

An explanation is offered for the unexepected presence in some steels of more austenite when quenched in oil than when quenched in water. It is suggested that the more violent quenching stresses actually deform the austenite grains and cause transformation.

IT is little short of platitudinous in these days to comment upon the enormous collection of data on the thermal hardening of steel which has been offered by experimenters in the last five years. New theories have been evolved compatible with the new information and the outstanding trend of the new conceptions is toward simplicity. Perhaps nothing is more largely responsible for the production of adequate theories of the hardening of steel than the availability of accurate quantitative measurements properly distributed over the field of investigation. Lately there have been offered, in greater number, series of measurements made with one variable—and only one variable—changing through a range of values during an investigation. As examples, measurements of

A paper presented before the Spring Sectional Meeting of the Society, Schenectady, May 29, 1925. The author, E. C. Bain, member A. S. S. T., is metallurgist, Union Carbide and Carbon Co., Long Island City, N. Y.

EDITOR'S NOTE: While the author describes the behavior of chromium austenitic steels and not manganese or nickel steels, yet the transformations involved in cold-work hardening of a steel such as the Hadfield manganese steel, must occur in precisely the same manner. Here, then, is a general explanation of the hardening of these steels by cold work.

hardness, atomic structure, specific gravity, magnetic properties, thermal points, etc., have been obtained in various series as they are affected by changing the composition, quenching temperature, drawing temperature or size of specimen. The utilization of the X-rays for metallographic investigation has given a few remarkably significant data when considered in connection with other facts. However, it is probable that the work of fitting together the collection of various fragments of knowledge into a consistent whole is second to no other activity in importance.

One of the most useful aids to the understanding of the phenomena involved in the hardening of steel is the division of the causes of hardening into two general processes. The first is the result direct of the allotropic change and the second is the development of slip-interference by precipitation of effectively sized particles of carbides. Recently it has been shown that by taking advantage of the unique product of the allotropic change in iron, a marked hardening is effected when the total carbon present is much too little to function as an appreciable auxiliary to hardening. If iron were not allotropic and possessed merely a considerable solubility for carbon at high temperatures and a much reduced retention of carbon at room temperature, we should still be able to harden this iron-carbon alloy thermally with the production of troostite, but by this method (paralleling the heat treatment of duralumin) we could not possibly hope to obtain nearly the strength or hardness found in the familiar tool steels.

The development of the unique constituent resulting from the rapid occurrence of the allotropic change obviously implies the prior existence of the high temperature form of iron or austenite. Since austenite is of necessity the parent substance of martensite, no justification need be given for intensive study of this condition in steel. Indeed in recent years it has begun to receive from experimenters attention fully commensurable with its basic importance. It will be remembered that the Henry Marion Howe memorial address in 1925 was devoted largely to gamma iron metallurgy. Dr. J. A. Mathews discussed the nature of austenite in an exhaustive manner and added greatly to our store of information concerning its properties. The present writer, after the discovery of the atomic structure of austenite, has found peculiar interest in the study of its persistence at lower temperatures after quenching as affected by additional materials in alloy steel.

The present paper attempts to bring together in one discussion specific information upon the effects of various elements mechanically stabilizing the high temperature form of iron, and from a consideration of these unavoidably fragmentary evidences to stimulate some contemplation of the atomic mechanisms responsible for the changes in properties brought about by heat treatment.

Above 1650 degrees Fahr. (900 degrees Cent.) pure iron exists in the gamma iron condition. As is well known, this form of iron, like alpha iron, is of a cubic crystalline type, but with a different arrangement of atoms, a form, in fact associated with greater ductility than the alpha form. Upon cooling through this temperature, a rearrangement of atoms occurs and a new distribution of grains is formed starting from a number of nuclei. Recently, by a unique method of extremely rapid cooling, pure iron has been depressed through this temperature range so rapidly that it has been hardened almost comparably to steel. It is generally conceded that this hardening is due either to the formation of a grain size extremely minute (probably colloidal) or the development of its metallurgical equivalent, a system of grains having imperfect crystallinity. Further it has been shown that for this type of hardening in steel, such a rate of cooling is required as will retard the consummation of the atomic rearrangement until the temperature has been lowered to about 650 degrees Fahr. (350 degrees Cent.). Presumably at this temperature atomic rearrangement is still easily practicable, but grain growth tendencies are slight. In general, the addition of foreign elements to the high temperature solid solution retards the change in a manner to permit of much less rapid cooling, i. e., less drastic quench. In this connection the effect of carbon, manganese, nickel, chromium and tungsten has been intensively studied. The mere existence in solid solution in iron of any of these elements assures us of a stronger average bonding between the adjacent atoms than is found in pure iron. This stronger bonding may perhaps discourage easy atomic rearrangement and thereby act to retard the series of changes accompanying the allotropic transformation. At any rate, having developed in these alloy steels a number of nuclei of alpha iron within the grains of gamma iron, grain growth would be much less likely to operate effectively than in pure iron. (It has been shown that solid solutions re-crystallize after cold work at a considerably higher temperature than do pure metals.)

These elements, commonly incorporated with iron to form familiar steels, strangely enough have two distinct immediate effects on the allotropic transformation. Carbon, nickel and manganese all contrive to lower the temperature of transformation whereas chromium and tungsten (and silicon as well) appear to raise the temperature for the allotropic change. It would constitute a plausible explanation if we were to conclude that the addition of these various elements which lower the point of transformation, operated by simply shifting the change to a temperature of lower atomic motion, but obviously we cannot use this explanation in connection with the elements chromium and tungsten, which also act to permit slower cooling rates for hardening. Whether or not that is the correct explanation in the case of carbon, manganese, nickel, etc., seems to the author to be a matter of minor importance. The explanation is inadequate for the whole of the phenomenon of austenite persistence, and therefore it would seem preferable to consider, in the absence of further information, the influence of stronger inter-atomic bonding found in all solid solutions. In the case of tungsten and chromium the effect upon the transformation appears as an increased sluggishness.

Just as greater rapidity of quench and the addition of elements in solid solution in austenite both tend to retard the completion of the allotropic change, grain growth and carbide precipitation, so that martensite can be formed, so still more drastic treatment and further increase in the amount of solute metal in solid solution tend to cause the retention of austenite itself permanently at room temperature. With the addition of carbon alone, steel may be obtained largely austenitic at room temperature after a severe quench from high temperature. With combinations of two or more of the usual elements in the solid solution it is not difficult, even after moderate quenches, to retain practically pure austenite. As is well known the austenite retained after the quench may be permitted to transform into alpha iron (not always in a form having the hardness of martensite) by reheating to various temperatures below the transformation point. In all steel this change takes place very slightly, if at all, at room temperature, but may begin at temperatures only slightly higher than boiling water. Other steels must be reheated at a dull red heat in order to effect the decomposition of the retained austenite.

It would seem reasonable, therefore, as a matter of first approxi-

mation to consider the temperature to which the austenitized steel must be heated for decomposition as a measure of the persistence or apparent stability of the various austenites. It is not necessary that the steel be wholly austenitic in making such determinations, for means are available for discovering the release of even small proportions of austenite. Sensitive volume change measurements are preferable, for in this method the allotropic change is the only one known which can cause an expansion of the steel. Thermal studies are aften ambiguous because of the fact that carbide precipi-

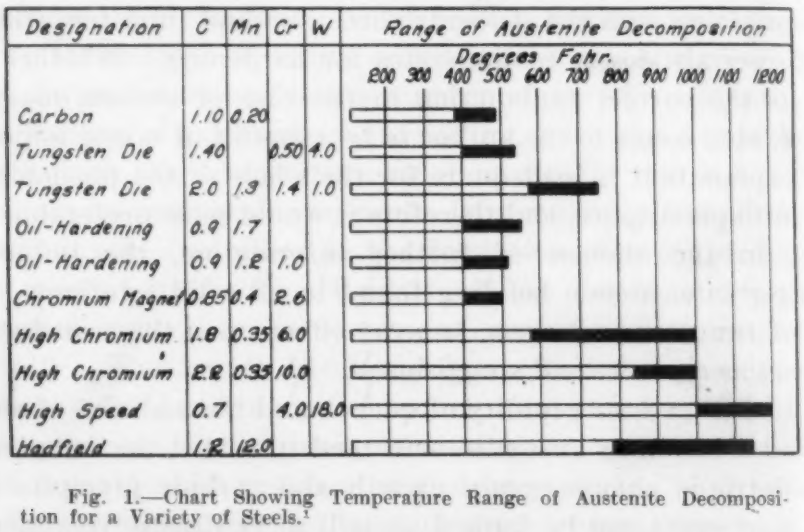

Fig. 1.—Chart Showing Temperature Range of Austenite Decomposition for a Variety of Steels.[1]

tation also causes heat evolution. In some cases accurate hardness tests serve admirably, but in some steels the increase in hardness caused by the austenite decomposition is approximately balanced by the softening accompanying the growth of carbide particles above the critical size. Again in some steels which have been studied there is no marked hardening at all as the austenite is released due to the fact that grain growth in the alpha iron takes place with sufficient rapidity from only a few nuclei to give little grain refinement. Whether or not the product of the change of preserved austenite is martensite depends on this matter of grain growth both in alpha iron and in the carbides. If the carbide precipitation precedes the allotropic change, as it appears usually to do, then the product is very much like troostite. In some steels the marked secondary hardness developed upon drawing at a high temperature

[1]For the figures on carbon steel and manganese steel the author has depended upon a number of published results from which inferences may be drawn,—notably the works of Howard Scott and John Howe Hall.

points strongly to the formation of an extremely fine grained alpha iron which might be consistently called martensite. Acicular markings are rarely seen in these materials.

The chart in Fig. 1 shows the range of temperature over which the austenite retained in various steels is decomposed. Clearly enough, the temperature range for a reaction of this sort does not lend itself to accurate delineation. For that reason a considerable range of temperature is shown in black in the diagram. The figures are doubtless subject to considerable inaccuracies. The attempt has been made in the chart to represent the lowest temperature on the one hand at which the decomposition becomes appreciable. At this rate a long time will be required for the reaction. The higher temperature indicated is actually less significant, but is intended to represent a temperature at which the reaction would complete itself in a few minutes. The range of temperature has a further significance. During the heat treatment the carbide particles are dissolved in austenite, and the very nature of this process implies concentration gradients. Unless one heats the specimen long enough to grow very large grains, complete homogenization does not follow. Accordingly, when the austenite is reheated to permit the allotropic change, various regions will of course transform at different temperatures, regions rich in alloy will persist at higher temperatures. As an example of this condition, it will be noted that a 6 per cent chromium steel is shown as beginning to transform under 600 degrees Fahr. (315 degrees Cent.), whereas another steel, essentially identical except that it contains 10 per cent chromium, is charted as initiating the change only at 840 degrees Fahr. (450 degrees Cent.). The significance of this point doubtless lies in the fact that with the lower chromium steel there were some regions which contained a comparatively small amount of alloy, whereas in the higher chromium steel there were no such regions. The decomposition is completed in a short time in both steels by heating at 1000 degrees Fahr. (537 degrees Cent.).

It will be noted that a tungsten die steel is reported as having little more stability as regards austenite than plain carbon steel, although there is present 4 per cent of tungsten. It is quite likely that prior to quenching sufficient time and temperature was not permissible to get into solution nearly all of the tungsten present. Experience indicates that without considerable chromium, tungsten is reluctant to enter into the gamma iron solid solution. Conse-

quently we find little effect on the persistence of austenite contributed by the 4 per cent tungsten as ordinarily heat treated. In short, the chart must be taken as only a first approximation of the effect of various alloys, but interpreted in the light of the familiar behavior of the various elements it illustrates fairly well the trend of the processes in operation.

In general, in the case of delayed or inhibited reactions in the solid state the thermodynamic instability of the material increases more and more as the temperature is lowered below the normal temperature for the reaction. When kindled or released the reaction takes place the more violently the greater the range of retarded action. Undercooling, in general, is this type of phenomenon. Acting against this tendency is the increased sluggishness of atomic motion caused by reduction of temperature. In the case of austenite we are dealing distinctly with an undercooling phenomenon in which the degree of undercooling has taken the material into a range of extreme atomic immobility. Any treatment which will encourage atomic mobility will exert a tendency to permit the restoration of equilibrium or at least effect an approach to equilibrium. Mechanical work or deformation of a crystal grain of austenite results in a gliding of layers of atoms upon one another. These atoms *in transit* have temporarily the characteristics of increased mobility. It would therefore not be surprising to find that the simple deformation of preserved austenite might permit a local consummation of the allotropic change which constitutes the restoration of equilibrium.

In this connection the author has quenched in oil a high chromium steel (Cr 10%; C 2%) after holding some time at a temperature near the solidus. The result is a comparatively ductile material essentially non-magnetic. Deformation in the cold was brought about under the hammer until the section was reduced approximately 15 per cent. The original hardness of the quenched steel was about 40 Rockwell "C" and after deformation it measured on the hammered surface 58 to 61 Rockwell "C," an inordinately large increase in hardness. Further, the material was quite definitely attracted by the magnet after the cold work. Both of these changes point most significantly to the formation of alpha iron from austenite and likely indicate that particular condition characterizing martensite. The microscope does not reveal with any clarity the nature of this altered material, but gives us some

knowledge of its distribution and extent. Fig. 2 is a photomicrograph of the material showing what appears to be "X-bands." At any rate the traces of slip are left in the etched grains. The hardening is large for such an apparently small amount of work. The comparative X-ray patterns in Fig. 3 show the production of

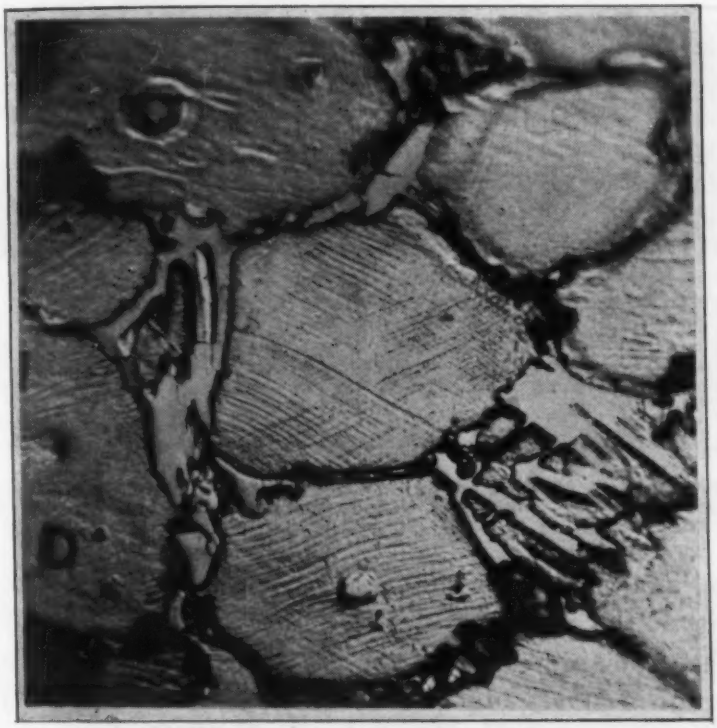

Fig. 2.—Photomicrograph of Austenitic Chromium Steel after Cold Deformation. The Slip-bands are Accompanied by Unusual Hardness and Probably are Thin Layers of Alpha Iron in a Condition Resembling Martensite.

alpha iron lines by the cold work, demonstrating beyond any doubt that the rapid hardening by cold work of austenitic steel is accompanied by the allotropic change.

It will be recalled that Dr. J. A. Matthews in his brilliant discussion gave irrefutable proof that at times an oil quench contrives even with its lower cooling rate to retain more austenite than the drastic water quench. The present writer checked over a series of results on 20 per cent nickel steels with various carbon contents and found most pronounced effects of the same sort. Since that time it has been a matter of intermittent study to discover if possible the reason for this peculiar circumstance. In the light of our knowledge of the large internal stress set up in steel by the quench-

ing process it appears conceivable that within some regions of a specimen of quenched steel these stresses may exceed the elastic limit of any austenite existing at the time. The severity of the water quench would probably cause the stress to exceed the elastic limit throughout a much greater extent of the specimen than the

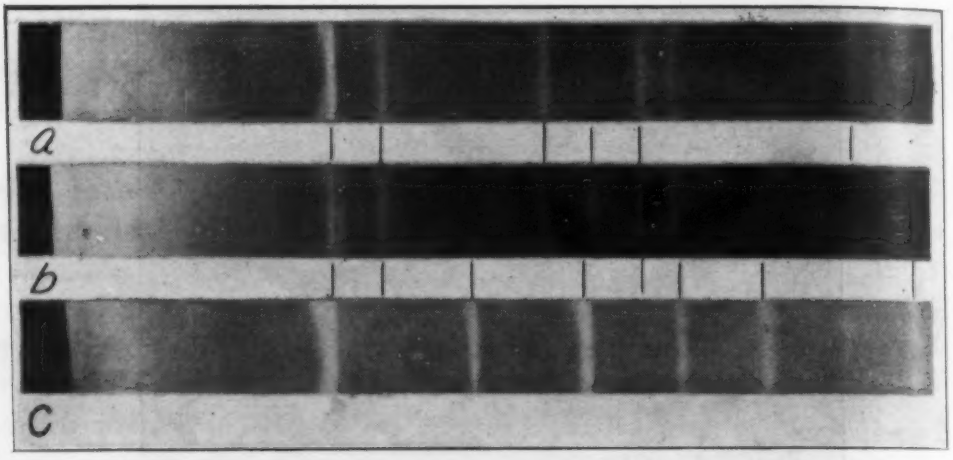

Fig. 3.—Comparison of Three X-ray Crystallograms. (a).—Austenitic Chromium Steel. (b).—Same Steel after Cold Work. (c).—Ordinary Alpha Iron to Identify New Faint Lines in (b).

oil quench. Particularly would this be true if the stresses were only barely within the range of elastic deformation in the case of the oil quench. The application of these stresses may be at a time when the austenite is at a more elevated temperature, and it may well happen that the deformation resulting would be sufficient to provide the condition of mobility required for austenite decomposition. Whether or not this is the true explanation for the unexpected reversal of oil-quench and water-quench effectiveness, nevertheless it takes into consideration the known behavior of the materials and is submitted here as a first hypothesis explaining the observation.

MAGNETIZATION AND CRYSTAL ORIENTATION

By W. E. Ruder

Abstract

Single crystals of silicon steel of varying orientation were tested for magnetic permeability. Wide variations were found between the magnetization of the strips (10 × 0.5 × 0.025 inches) depending upon their crystal orientation with respect to the direction of impressed magnetic field. The permeability of crystals having their cube edges perpendicular and parallel to the direction of the applied flux was from 10 to 25 times that of crystals having their cube edges at an angle. The lowest magnetic permeability was obtained when all edges were at 45 degrees with the direction of flux. Over 100 samples were examined. Curves and photomicrographs are given showing the change and magnetization as the orientation changes.

EXPERIMENTAL data relating to the physical properties of single crystal grains of metals are coming to be of considerable importance now that the method of X-ray analysis has given us a more exact knowledge of the structure of the atom. Science is groping for a solution to the problem of the arrangement of electrons in the atom which will satisfy the multitude of requirements imposed by the known physical and chemical properties.

Experiments, made in 1917-1918, in connection with a study of the basic laws governing the growth of crystal grains in metals, resulted in the production of a large number of single grain strips of silicon steel, varying in width from ½ to 1½ inches and in length from 12 to 24 inches, and approximately 0.025 inch thick. The material was a 3.25 per cent silicon steel, such as is commonly used in electrical apparatus, and contained only such other elements as are usually found as impurities in a good grade of mild open hearth steel.

While we had available for study about one hundred of these strips, only a comparatively few were perfect single grains. In some cases there was a tendency for small grains to invade the

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A paper presented before the Spring Sectional Meeting of the Society, Schenectady, May 28, 1925. The author, W. E. Ruder, member A. S. S. T., is metallurgist, Research Laboratory, General Electric Co., Schenectady, N. Y.

larger ones, due to lateral strains, resulting from the necessary cutting of the specimen. In other cases, small areas maintained their orientation so persistently that the condition of strain and temperature used to produce the large grain growth had no effect on them.

In order to study their magnetic properties, the large crystal grains, of varying shapes and sizes, were first cut into ½ x 10

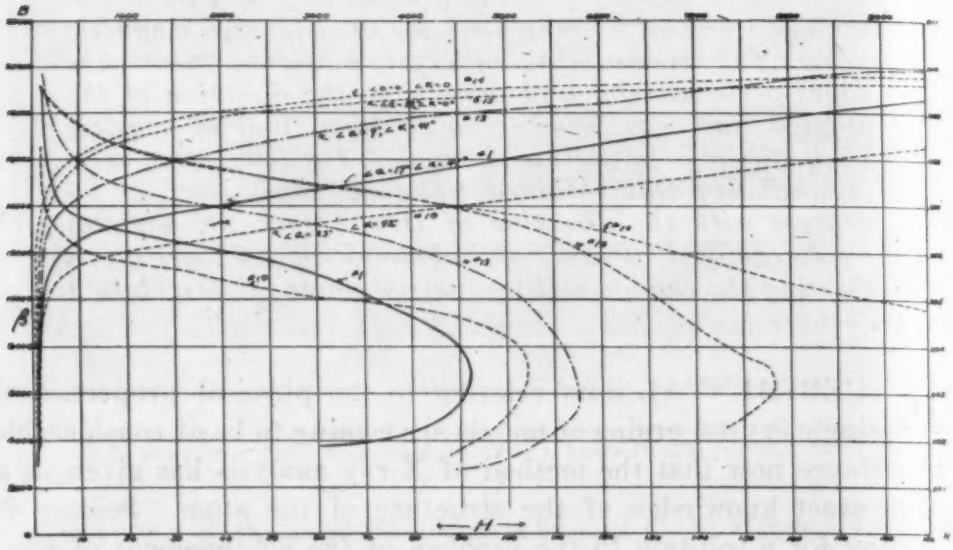


Fig. 1—Magnetization and Permeability Curves for Crystals of Widely Varying Orientation.

inch strips to fit a Burrows permeameter. This cutting had to be done with extreme care, as any strain introduced resulted in a reorientation of the strained area on reannealing. The strips were all reannealed at 1832 degrees Fahr. (1000 degrees Cent.) in a vacuum, before testing.

Preliminary magnetization and permeability tests showed a wide variation in properties of these strips which, according to previous knowledge, having practically the same chemical composition and heat treatment, should have been about the same. Certain strips had values corresponding more nearly to those usually associated with the purest iron, while others were much lower than high silicon alloy. Fig. 1.

When the strips were etched it became at once apparent that in those having high magnetic permeability the shiniest grains predominated, while in the poorer ones the larger grains were dull in appearance.

When examined by means of a small exploring coil which

could be moved along their length, it was found that marked changes of induction occurred at the boundaries of grains and that the greater the change in the angle of orientation with respect to the direction of the applied field, the more abrupt were these changes in induction.

In order to get some kind of a measure of the angles formed

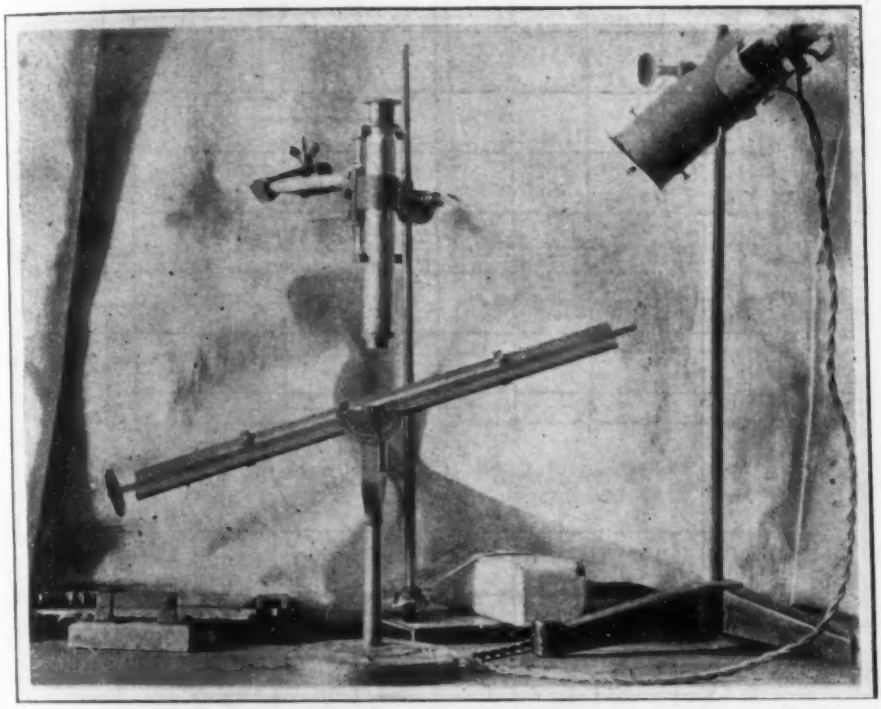


Fig. 2—Apparatus Used for Measuring Orientation.

by the faces of these cubic crystals with respect to the direction of magnetic flux, a simple apparatus, as shown in Fig. 2, was constructed. This consisted of a small table which could be rotated in three planes and the angles of rotation measured in each case. The strip to be examined was clamped to this table and the light from a small arc was directed upon it at a predetermined angle. The table was then rotated until a point of maximum reflection was observed through the reading tube. In this way the angle of orientation in each of the three planes was noted. This angle about the horizontal axis, perpendicular to the length of the strip, was designated "a"; the angle about the axis parallel to the length of the strip was called "b"; and the angle about the vertical axis was called angle alpha.

It was soon found that unless the angle "a" happened to be fairly large, measurements of the angle alpha by this method was unreliable, but that, upon breaking the strips, this angle could be measured directly.

On comparing these angles with the magnetic data, it was

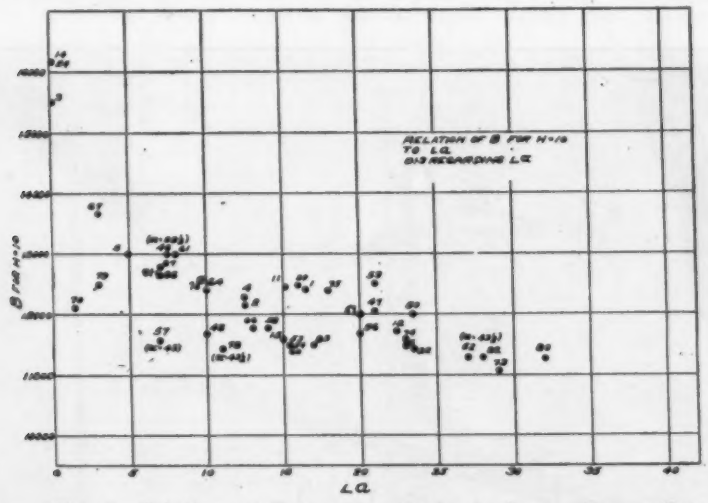


Fig. 3—Relation of B for H = 10 to Angle A, Disregarding Angle Alpha.

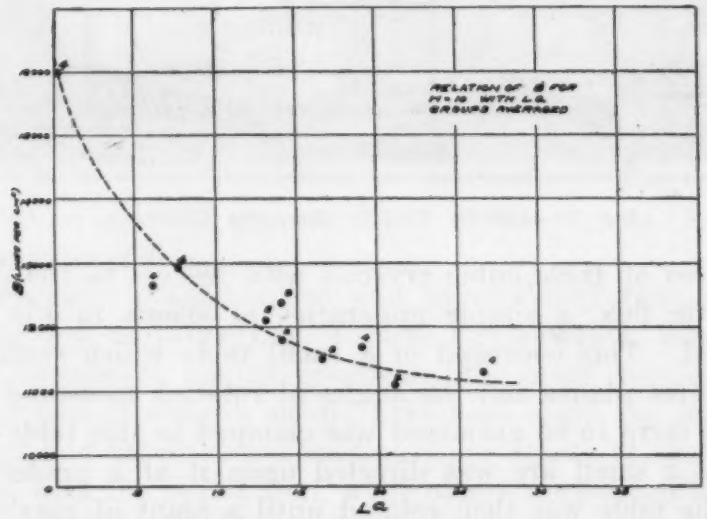


Fig. 4—Relation of B for H = 10 with Angle A. The Figures Show the Number of Samples Averaged for Each Point.

found that there was apparently no relation between the maximum permeability and the orientation of the crystals. This is not surprising, as this point on the magentization curve is most sensitive to small differences in composition, internal strain, and heat treat-

ment. At the higher densities, however, a distinct relation was noted between magnetization and angle "a." The angle "b" appeared to have no effect whatever at any density, while the effect of angle alpha was as yet uncertain, as we had no reliable measurements for it. For comparison, the points B for

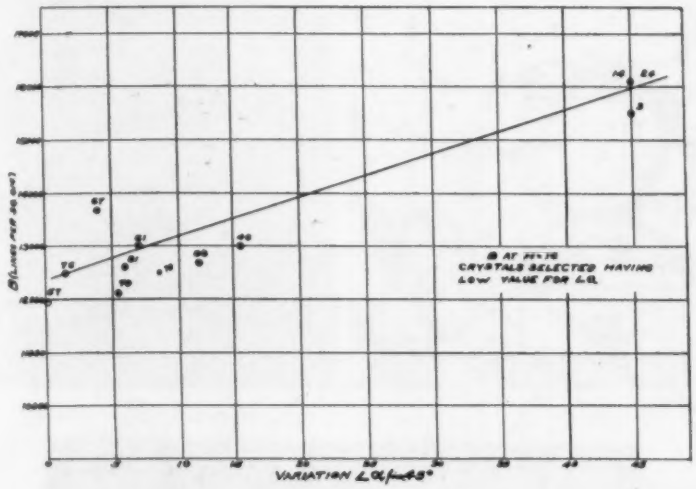


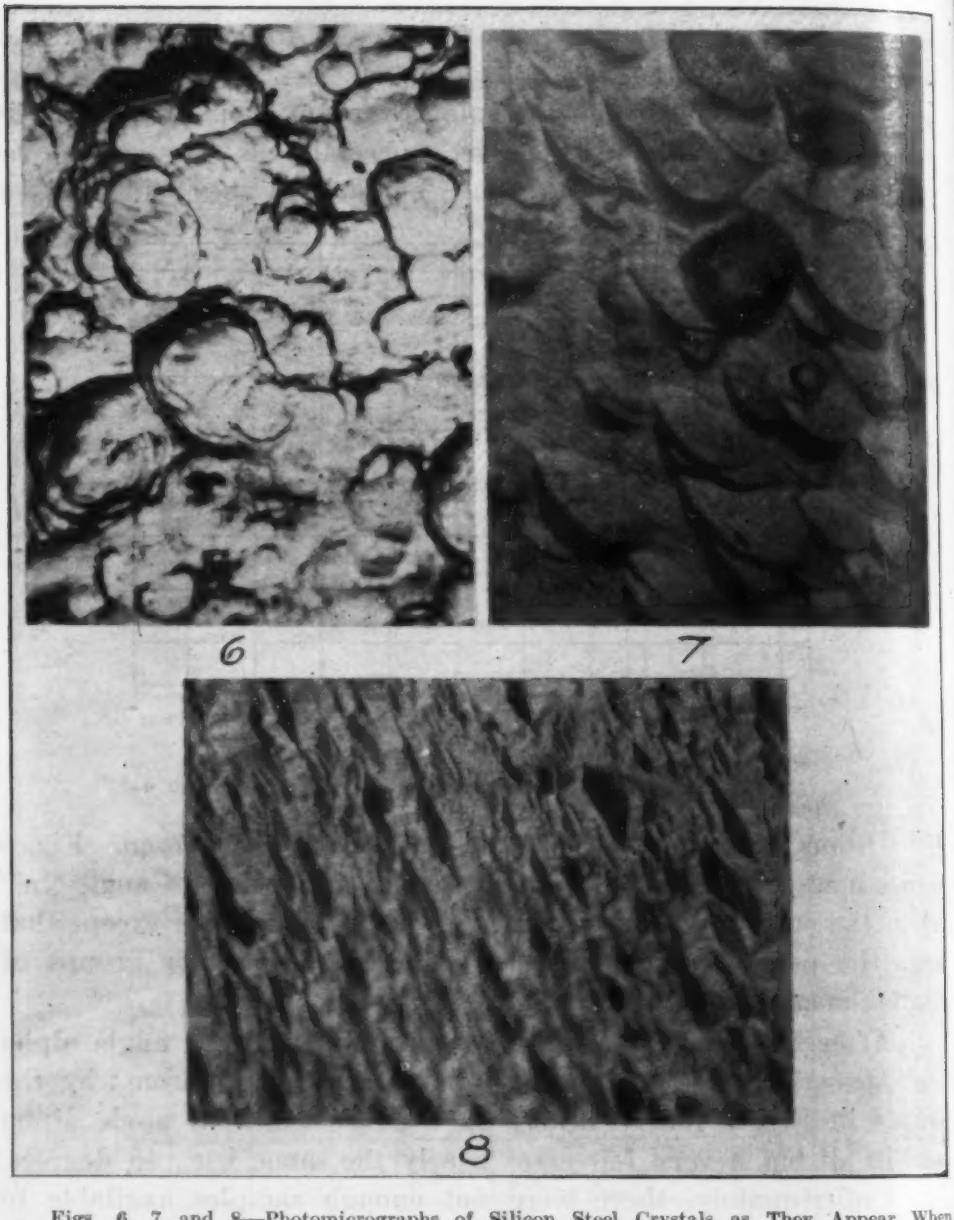
Fig. 5
Relation of B to Angle Alpha. Crystal Selected Having Low Values of Angle A. Abscissæ Variation of Angle Alpha from 45 Degrees.

H = 10 on the magnetization curve was arbitrarily chosen. Fig. 3 shows how the points fall and gives the relationship to angle "a" when the other angles are ignored. Fig. 4 is the same except that here the points represent average angle readings for groups of similar magnetization values.

After the tests the samples were broken and the angle alpha read directly. It then became apparent that the reason why the points in Fig. 1 fell so nearly on a curve was that angle alpha was in all but a very few cases nearly the same, i. e., 45 degrees.

Unfortunately, there were not enough samples available to give a sufficient range in orientation, so that a good curve could be obtained with one angle while keeping the other constant, though this was attempted and Fig. 5 shows that the angle alpha also has a marked influence upon the magnetization.

Photomicrographs, Figs. 6, 7, and 8, show how these crystals appear when deeply etched. Fig. 6 is angle alpha = 0 degree, angle "a" = 0 degree; Fig. 7 is angle alpha = 51 degrees, and angle a = 7 degrees, and Fig. 8 is angle alpha = 51 degrees, and angle a = 23 degrees. The magnetization values are given below



Figs. 6, 7 and 8—Photomicrographs of Silicon Steel Crystals as They Appear When Deeply Etched. Magnification 350X. Fig. 6—Angle Alpha = O Degrees; Angle A = O Degrees; B = 16200 for H = 10. Fig. 7—Angle Alpha = 51 Degrees; Angle A = 7 Degrees; B = 12600 Degrees for H = 10. Fig. 8—Angle Alpha = 51 Degrees and Angle A = 23 Degrees; B = 11600 for H = 10.

each photomicrograph. Microscopic examination serves as a check on the measurements of angles, though by this method, only wide variation in orientation may be observed.

The results, aside from being somewhat obscured by the two angles involved, are further complicated by a variation in silicon content from 2.75 to 3.45 per cent. This variation in silicon will

account for a difference of about 450 in saturation value.

More exact measurements of the angles, particularly angle "a," and more data must be obtained before an exact formula, expressing the relation of magnetic permeability to orientation, can be given. It may be assumed, however, that the relation of angle "a" and angle alpha to this permeability must be the same,

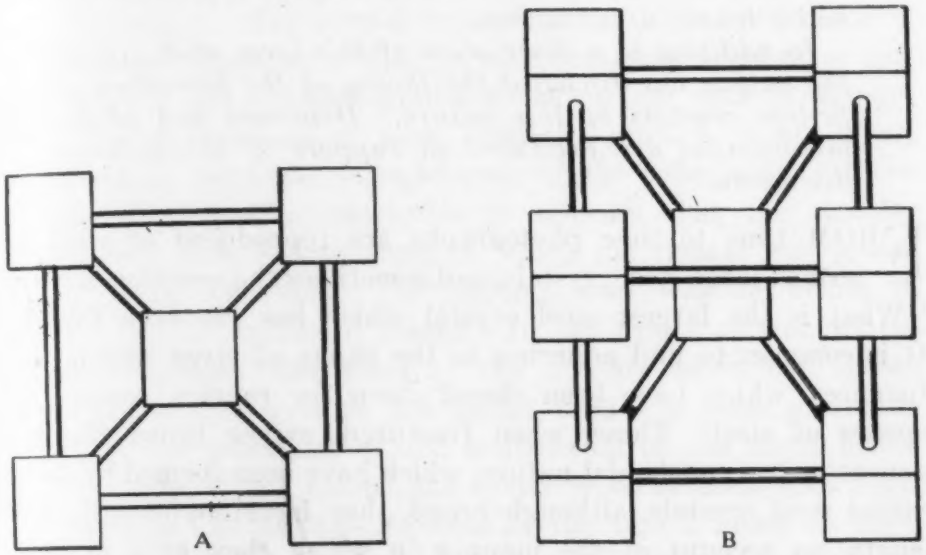


Fig. 9a—Shows the Position of the Crystal In Which it has the Greatest Permeability When the Magnetic Flux is Perpendicular to the Page. Angle A = O Degrees and Angle Alpha = O Degrees. Fig. 9b—Shows the Position When Angle A = 45 Degrees and Angle Alpha = O Degrees. The Position of Minimum Permeability Not Shown, is that Seen When Looking Directly at the Corner of the Cube, instead of the Edge as in Fig. 9b.

as they are angles of revolution around axes in the same plane, perpendicular to the path of the applied field.

Fig. 9 shows (a) the position of the crystal in which it has the greatest permeability when the magnetic flux is perpendicular to the page (angle "a" = 0; angle alpha = 0), and (b) shows the position (angle "a" = 45 degrees; angle alpha = 0). The position of minimum permeability, not shown, is that seen when looking directly at a corner of the cube instead of an edge as in (b).

The data given does apparently justify the conclusion, however, that magnetic permeability at medium and high densities is a function of the angle of orientation of the crystal around the vertical and the horizontal axis perpendicular to the direction of the applied flux. Although this conclusion leads to some interesting speculations as to the probable paths of the free electrons in the magnetic iron atom, no attempt is made, at this time, to do more than set down the data as such.

A REMARKABLE STEEL CRYSTAL

By J. S. G. Primrose

Abstract

The author of this paper has described what is believed to be one of the longest steel crystals which has ever been found. This crystal was taken from the pipe cavity of a 50-ton ingot of mild steel and weighed 3 pounds and had a length of 19 inches.

In addition to a description of this large steel crystal the author has discussed the theory of the formation of fir-tree crystals of this nature. Diagrams and photomicrographs are presented in support of the author's discussion.

FROM time to time photographs are reproduced of what are termed large steel crystals, and sometimes the question is asked: "What is the largest steel crystal which has yet been found?" It is common to find adhering to the banks of large steel-melting furnaces, which have been closed down for repairs, considerable masses of steel. These, when fractured, expose broad facets of a more or less conchoidal nature, which have been formed by slowly cooled steel crystals, although broad, they have not usually much length on account of the manner in which they have mutually interfered with one another during their own growth out of the liquid magma. In the course of the extremely slow cooling which takes place, very marked segregation often occurs with the production of exaggerated laminations of pearlite areas, and high concentrations of phosphide eutectic.

The most fruitful source of the much more beautiful dendritic or 'fir-tree' crystals is, however, to be found in the cavities in the cast steel ingots, usually formed in the feeding-head of the ingot or casting. The larger the cooling mass of metal, and the higher the teeming temperature, assisted by a sand-covered top, the more chance there is of the feeding-head remaining open for a sufficient time to form large crystal growths. The sides of the ingot cavity are not infrequently richly encrusted with incipient crystals, only a short length of which projects from the interlocked mass of solid metal crystals forming the sides. It is only when specially favoring circumstances enable the off-shots from the top crust of metal in the

A paper by J. S. G. Primrose, member A. S. S. T., and metallurgist with the Richard Johnson & Nephew, Ltd., Bradford Iron Works, Manchester, England.

pipe to be fed just sufficiently by the retreating molten metal that long, straight fir-trees of steel are formed.

Most steel makers and metallurgists agreed with Professor A. Sauveur when he described as remarkable the reproduction in his magazine "The Metallographist," for January, 1899, of a beautiful steel crystal then in the possession of Professor D. Tschernoff of St. Petersburg. The crystal measured over 15 inches in length, and it has been frequently cited as an example of the fir-tree formation of steel as it solidifies against a cool surface, such as an ingot mold. The interlocking of such dendritic growths must impart a considerable resistance to sundering of the solid metal. From Professor Tschernoff's description it appears that the circular ingot of mild open hearth steel, in which the crystal was found, weighed about 100 tons. The sinking head was 39 inches in diameter, and 59 inches in height. In the upper portion of the pipe were incrusted the roots of the crystals which had grown downwards as the level of the liquid steel had been gradually lowered by the solidification and contraction of the metal below. The side walls of this funnel-like cavity were covered with pyramid points of the crystals formed in the liquid metal at right angles to the cooling surfaces. A few crystals were found isolated, but the most of them were united laterally, forming twin crystals, with their apices frequently uniting with the lateral pyramids. The sketch Fig. 1 gives a diagramatic view of how the crystals clustered round the walls of the ingot cavity or grew downward in pipe-like stalactites.

The Scotch Crystal

Many workers have searched in vain to find such a large crystal, and although numerous clusters or nests of crystals have been found adhering to the sides of the ingot cavity or projecting only a few inches, it is somewhat rare for crystals even 12 inches long to be discovered. Such crystals have been illustrated in papers read by Dr. Stead and others, but some 15 years ago it was the good fortune of the writer to acquire a unique specimen of fir-tree steel crystal, which besides being perhaps the longest yet found has some interesting features which are worth recording. When it was broken out of the pipe of a fifty ton ingot of mild open hearth steel, the crystal weighed 3 pounds and measured 19 inches in length. It was quite easily detached from the roof of

the cavity, and had no less than eleven small "twin" crystals showing incipient growth at various points along its length, but chiefly at the lower end, where four had commenced to point their way upwards. At the top end was an oval handle, the formation of which can perhaps be accounted for by assuming that the steel

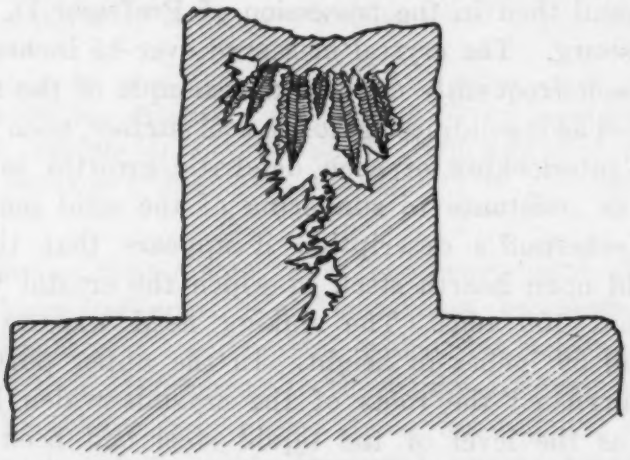


Fig. 1—Steel Dendrites in Sinking Head of Large Ingot. (After Tschernoff.)

was in the dripping state as this portion was growing, and thus the pointed off-shoots which have all been left projecting from the central axis below this 3-inch handle, would, for this length, be melted off. This oval portion is quite corded in appearance, with little frozen rivulets of steel which are sufficiently rough to represent the bases of the pyramids, although the points are gone. The primary axis of the crystal is practically straight the whole length, and the secondary axes are at right angles both to the primary axis and to one another. The tertiary axes of the crystal are quite obvious from the photograph reproduced in Fig. 2.

The Formation of Crystals

To Dr. Stead we owe the clever illustration of what occurs in steel as it cools from the liquid to the solid condition. He says: "The fine fir-tree crystals grow steadily forward from the cold surfaces of the containing molds. The crystallites develop branches in three directions corresponding to the axes of the cube, and these branches throw out similar branches themselves. Eventually, parts of the most fusible portion are trapped between the branches, and are the last to solidify." The diagram he gives in Fig. 3 represents the gradual growth of three separate crystals, which feed and develop out of the liquid, abstracting the purer iron and con-

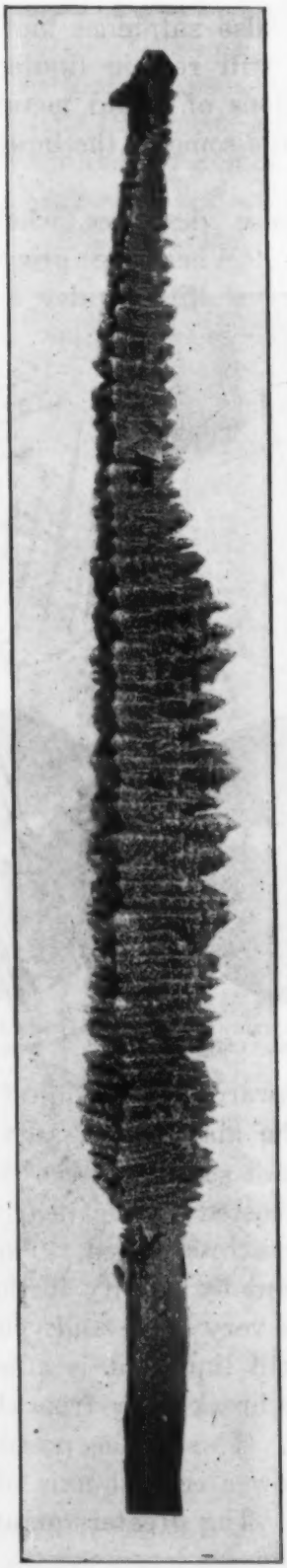


Fig. 2—Photograph of Large Scotch Steel Crystal which Measured 19 Inches in Length.

centrating the carbon, also sulphides and phosphides if present, in the portions which still remain liquid. The white junctions represent the last portions of liquid metal which form envelopes around the crystals, while some of the liquid is trapped within the crystals.

Professor Howe also describes what happens when steel freezes in an ingot— "When the greater part of the metal has become solid, the crystallites bridge across from the internal walls of the inside of the ingots as they slowly solidify, and this

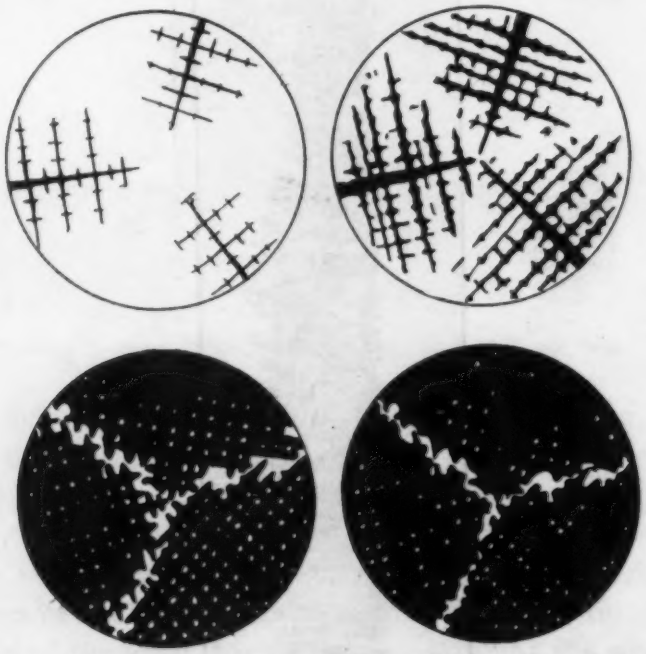


Fig. 3—Diagram Representing Gradual Growth of 3 Separate Crystals. (After Stead).

mass sinks or sags downwards as the liquid in the central column of liquid contracts. The mass which sags down is free to flow as a whole, as it could not sag if it were rigid. The bases of the fir-tree crystallites are rooted in the nearly solid walls, and the branches are more or less interlocked. This prevents them from falling to any great extent by gravity to the bottom of the liquid column. If the ingot is very large and cooled very slowly, when the central column is still liquid, it is almost certain that many of the fir-tree crystallites break away from the sides and fall to the lower part of the ingot. This is the possible explanation of the fact that steel in the lower central axis of large steel ingots is purer than the average. The greater quantity of the crystallites

do not fall, so that the central mass,—liquid and solid—sinks most freely in the center of the ingot, and the bridges of fir-tree crystallites form parabolic inverted domes. This is best shown by a sulphur print taken of a medial section of such an ingot."

A photomicrograph of one of the "twins" taken from the

Fig. 4—Photomicrograph of One of the Twins Taken From the Large Scotch Crystal Shown in Fig. 2. Magnification 50X.

large crystal here shown is given in Fig. 4 at 50 diameters. The white ground-mass consists of the first formed ferrite crystal network with the entangled slag films which show up as grey patches of irregular shape. Between the branches of the fir-tree ferrite occur the pearlitic areas, resulting from the slowly cooled and partly diffused high carbon portions entrapped originally in smaller spaces by the growing ferrite mesh. The pearlite is shown dark as the result of etching in a weak 1 per cent solution of nitric acid in alcohol.

DETERMINATION OF FURNACE EFFICIENCIES AND HEAT TREATING COSTS

By C. L. Ipsen

Abstract

The author shows that a statement of the efficiency of a furnace must be based on the operating cycle, and demonstrates by examples that the efficiency of an electric furnace chosen for illustration may range from 33 per cent to 78 per cent, depending on the cycle and the material to be heated.

He also shows that the cost of heat treating depends on many factors other than the installation cost of furnaces and the cost of fuel, the latter being in many cases less than the other individual factors.

The need for a thorough investigation of the over-all cost of heat treating is emphasized.

Introduction

EFFICIENCY ratings can readily be applied to such power equipment as motors, engines and pumps, where a definite relation exists between input and output at all loads and where any variation in load causes an immediate and corresponding variation in input. These ratings are, in general, well understood and form a definite basis for making comparisons and for calculating performance costs. The conversion of energy in a furnace and its absorption by the charge differs radically in many essential details from its conversion and use in such power equipment. Thus, considerable confusion and misunderstanding have attended efforts to apply similar efficiency ratings to furnaces.

An appreciation of the difficulties encountered can probably best be gained by considering certain details in the design and operation of a furnace to meet some specific heat treating requirements. Since a simple case will illustrate the various points in question most clearly, we will consider pertinent factors in the design and operation of an electric box type furnace for annealing certain forgings at 1650 degrees Fahr. (900 degrees Cent.) at the rate of 800 pounds per hour. Later we will consider the use of

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this same furnace for two additional purposes; heating die blocks at 1450 degrees Fahr. (790 degrees Cent.) and carburizing at 1650 degrees Fahr. (900 degrees Cent.).

The size of the furnace will be determined by the size of the forgings and by the time required for them to reach the furnace temperature. Data are available which assist in computing time of heating, but for irregular shaped forgings, most reliable and accurate results can best be secured by actual test. This test can be readily made by embedding a thermocouple in the heaviest section of the forging and noting the time required for it to reach furnace temperature when placed in a furnace held at the proper annealing temperature. For the case at hand it will be assumed that the time to heat the forgings as determined by this method, including charging and discharging time, is forty-five minutes. This will give a furnace charge of 600 pounds. It will be further assumed that the forgings are of such size and shape that a 600-pound charge will require a furnace working space 4 feet wide by 6 feet deep by 2 feet high. Wall thickness, insulating materials and door construction will be so chosen that the standby losses will be 15 kilowatts, including door losses when the furnace temperature has reached equilibrium at 1650 degrees Fahr. (900 degrees Cent.).

The heat absorption in kilowatt hours per hour of the charge is computed from the following equation:

$$\text{Kilowatt hours} = \frac{\text{Weight of forgings per hr.} \times \text{Spec. Heat} \times \text{Temp. Rise}}{3415}$$

Substituting values, and assuming initial temperature of work as 50 degrees Fahr.

$$\text{Kilowatt hours} = \frac{800 \times 0.160 \times 1600}{3415} = 60$$

Adding to this the losses, 15 kilowatt hours per hour, gives 75 kilowatt hours per hour as the total energy consumption. Experience shows that approximately 15 per cent additional capacity is desirable to insure rapid initial heating of the charge. Accordingly, the heating units for this furnace will be designed with a resistance such that they will draw a total of 85 kilowatts when connected to power lines of proper voltage.

In order to consider the case of operating this furnace on an 8-hour basis, it will be necessary to know the average losses during the idle periods at night, and for continuous operation for 5½

days a week, as well as to know the average losses over the week-end period. It will be assumed that the average loss over the idle period at night is 12 kilowatt hours per hour, and for the idle period during the week end is 7 kilowatt hours per hour.

To summarize the above conditions: The furnace is 4 feet wide x 6 feet deep x 2 feet high, with a connected load of 85 kilowatts. The standby losses are 15 kilowatt hours per hour at 1650 degrees Fahr. (900 degrees Cent.), the average loss during the night being 12 kilowatt hours per hour and during the week-end 7 kilowatt hours per hour. The furnace will heat certain forgings to 1650 degrees Fahr. at the rate of 800 pounds per hour in 600 pound charges.

Efficiency is usually defined as the ratio of output to input and is expressed in per cent. Input in the case of the furnace under consideration is obviously the input of electric energy which is converted into heat. This conversion is attended by no losses, so may be taken as the full heat equivalent of the electric energy used or 3415 B.t.u. per kilowatt hour. Output is clearly the heat absorbed by the forgings.

In giving consideration to the various efficiency ratings that follow, it should be understood that in using calculated values, furnace input must be computed as the sum of assumed heat losses plus the heat absorption of the metal. In other words, the efficiency ratio becomes

$$\frac{\text{Output}}{\text{Output} + \text{Losses}}$$

With a furnace actually in operation, this input can be readily and accurately measured with a watthour meter. The output in that case would be computed from weight and temperature rise of forgings annealed.

I. Full Load Hourly Efficiency

The efficiency of this furnace for any given hour of its operation at full load after temperature equilibrium is reached is expressed as follows:

$$\text{Efficiency} = \frac{800 \times 0.160 \times 1600 \times 100}{(800 \times 0.160 \times 1600) + (15 \times 3415)} = 80 \text{ per cent}$$

This value may be useful in making comparisons between different furnaces but has little value in computing costs, since no consideration is given to losses during idle periods.

II. All-Week Efficiency When Operating 48 Hours or 5½ Days Per Week at Full Output

The output of forgings in 48 hours is equivalent to 38,400 pounds.

The standby losses are as follows:

48 hours at 15 kilowatt hours per hour =	720
77 hours at 12 kilowatt hours per hour =	924
43 hours at 7 kilowatt hours per hour =	301
Total heat loss =	1945 kilowatt hours

$$\text{Efficiency} = \frac{38{,}400 \times 0.160 \times 1600}{(38{,}400 \times .160 \times 1600) + (1945 \times 3415)} \times 100 = 59.5 \text{ per cent}$$

III. All-Week Efficiency When Operating Three Shifts of 128 Hours a Week

The output of forgings in 128 hours is equivalent to 102,400 pounds.

The standby losses are:

128 hours at 15 kilowatt hours =	1920
40 hours at 7 kilowatt hours =	280
Total heat loss =	2200 kilowatt hours

$$\text{Efficiency} = \frac{102{,}400 \times 0.160 \times 1600}{(102{,}400 \times 0.160 \times 1600) + (2200 \times 3415)} \times 100 = 78 \text{ per cent}$$

IV. When Heating Die Blocks

The use of this furnace for heating charges of die blocks weighing 1200 pounds per charge, to 1450 degrees Fahr. (790 degrees Cent.) will now be considered. These die blocks are of such a size that four hours will be required for them to reach furnace temperature. It should be observed in this connection that the furnace output is controlled not only by the number of kilowatts connected load but by the rate at which the charge will absorb heat. The controlling factor is usually the latter, as more heat can usually be supplied in a given time by the heating units than can be absorbed by the charge.

The all-week efficiency, when operating 48 hours, or 11 heats will be considered. Standby losses are approximately proportional to operating temperatures. At the temperature of 1450 degrees Fahr. (790 degrees Cent.) the losses will thus become approxi-

mately 13, 10.5 and 6 instead of 15, 12 and 7 used at 1650 degrees Fahr. (900 degrees Cent.).

The output of die blocks per week will be equivalent to 1200 x 11, or 13,200 pounds.

The standby losses are as follows:

48 hours at 13 kilowatt hours per hour = 624 kilowatt hours
77 hours at 10.5 kilowatt hours per hour = 808 kilowatt hours
43 hours at 6 kilowatt hours per hour = 258 kilowatt hours

Total heat loss = 1690 kilowatt hours

$$\text{Efficiency} = \frac{13{,}200 \times 0.155 \times 1400}{(13{,}200 \times 0.155 \times 1400) + (1690 \times 3415)} \times 100 = 33 \text{ per cent}$$

The initial temperature of the work being assumed as 50 degrees Fahr.

This corresponds to an efficiency of 59.5 per cent attained when heating forgings; the difference in efficiency being due wholly to greater length of time required for the die blocks to reach furnace temperature with a corresponding decrease in tonnage output.

V. When Carburizing

The efficiency of the furnace when used for carburizing will be considered on the basis of eleven 12-hour heats per week, each heat having a gross weight of 3000 pounds. The net weight of the parts being carburized is 1500 pounds and the weight of pots and carburizing compound equivalent from the thermal standpoint to 1500 pounds of steel. At a temperature of 1650 degrees Fahr. (900 degrees Cent.) the following prevail:

Net output per week = 1500 × 11 = 16,500 pounds
Gross output per week = 3000 × 11 = 33,000 pounds

The standby losses are as follows:

132 hours at 15 kilowatt hours per hour = 1980 kilowatt hours
36 hours at 7 kilowatt hours per hour = 252 kilowatt hours

Total losses = 2232 kilowatt hours

$$\text{Gross Efficiency} = \frac{33{,}000 \times 0.160 \times 1600}{(33{,}000 \times 0.160 \times 1600) + (2232 \times 3415)} \times 100 = 52.5 \text{ per cent}$$

$$\text{Net Efficiency} = \frac{16{,}500 \times 0.160 \times 1600}{(16{,}500 \times 0.160 \times 1600) + (2232 \times 3415)} \times 100 = 36 \text{ per cent}$$

VI. Efficiency

Since full load input minus full load losses in power equipment always equals full load output, the efficiency may be cor-

rectly expressed as the ratio of input minus losses to input. Based, no doubt on this fact, some manufacturers have applied a similar rating to furnaces and taken as the efficiency the ratio of connected load (full load input) minus standby losses at a given temperature to the connected load, neglecting entirely the fact that full load output is largely a function of the rate at which the charge will absorb heat and also neglecting the fact that losses continue for a long period after the furnace is shut down.

Rated on this basis the furnace in question has an efficiency at 1650 degrees Fahr. (900 degrees Cent.), equal to

$$\frac{85 - 15}{85} = 82.5 \text{ per cent}$$

Assuming that the voltage at the furnace terminals is raised so as to increase the input from 85 to 100 kilowatts, this efficiency becomes

$$\frac{100 - 15}{100} = 85 \text{ per cent}$$

VII. Recuperative Furnaces

The use of recuperative furnaces for annealing is sometimes desirable. This introduces further complications in efficiency ratings. Let us assume in Example III that the outgoing charge imparts 50 per cent of its heat to the incoming charge. The overall efficiency of the furnace is then computed as follows; assuming as the output the total heat required to raise the charge to 1650 degrees Fahr. (900 degrees Cent.), and assuming the initial temperature of the work as 50 degrees Fahr.

$$\text{Efficiency} = \frac{102{,}400 \times 0.160 \times 1600}{\frac{(102{,}400 \times 0.160 \times 1600)}{2} + (2200 \times 3415)} \times 100 = 122 \text{ per cent}$$

Reviewing the foregoing examples, we find that full load efficiencies ranging from 33 to 78 per cent can be correctly applied to this single furnace and that much higher efficiencies are sometimes applied. This naturally leads to the conclusion that, unlike power equipment, furnaces cannot be given an efficiency rating without complete knowledge of the character of the load for which they will be used.

Determination of the cost of heat used in an electric furnace can readily be made, as the only cost involved is the cost of electric energy. This can be accurately measured with a watthour

meter. By measuring the input for a week and subtracting the heat absorbed by the charge during that time, the standby losses are obtained. Based on these losses, the cost of operation can readily be computed for various rates of production up to the capacity of the furnace.

In determining the cost of heat used in fuel-fired furnaces, particularly those fired with coal and oil, it is necessary to add to the purchase price of the fuel such cost items as handling, storing, pumping, air or steam for atomization, etc. In the case of oil, the cost of these items ranges from 1 to 3 cents per gallon, depending on local conditions. The standby losses of an electric furnace for a given cycle of operation and for a given temperature remain practically constant, since they involve only the small amount of heat conducted through the furnace walls and lost by radiation and convection. In fuel-fired furnaces there are further losses, including the heat carried out by flue gases and the loss due to incomplete combustion of the fuel. These losses vary widely with varying conditions of the fuel and varying amounts of air used. Accordingly, reliable cost data on fuel-fired furnaces can be obtained only after long periods of operation under normal production conditions. Cost data compiled from tests of short duration are often misleading on account of the greater watchfulness during such periods to maintain maximum efficiency than would prevail under normal production. One case is recalled where a 2-weeks' test on a sheet annealing furnace showed an oil consumption of 38 gallons per net ton, while the average oil consumption for 1-year's operation showed an oil consumption of 58 gallons per net ton.

The cost of heat for all types of furnaces varies widely with varying rates of production, as was clearly illustrated by the various foregoing examples. To those who are accustomed to placing electric furnace efficiencies at 75 per cent or higher, and fuel-fired furnaces at 40 per cent or higher, a study of the all-year efficiency of a heat treating plant would be enlightening. A study made in one large plant recently where gas- and oil-fired furnaces are used revealed an efficiency of 3.8 per cent gross, including carburizing and annealing boxes, or 1.7 per cent net. This efficiency was based on the heat content of the oil and gas consumed and the heat absorbed by the steel over a period of 1 year. Such facts as these indicate the thoroughness and care required in arriv-

ing at the cost of heat used for heat treating operations. It also emphasizes the danger of using costs based on such general theoretical values as are often found published on relative costs of various fuels.

Costs Other Than Fuel or Power

Up to this point our discussion has been confined to furnace efficiencies and cost of heat for carrying on heat treating operations. Many people who investigate heat treating costs and compare various fuels and furnaces, place chief emphasis on this phase of the problem without realizing that in many cases there are other factors of heat treating costs far more important than the cost of heat. Consideration of these other factors entering into the cost of heat treating will be taken up in the following order:

1. Quality of product, inspection and rejections
2. Cost of subsequent cleaning operations
3. Cost of subsequent machining operations
4. Maintenance of furnace and auxiliary equipment; Interruptions
5. Capital investment; Depreciation; Obsolescence
6. Labor, working conditions

1. Quality of Product; Inspection; Rejections

Entirely new physical properties are imparted to a piece of steel when it undergoes heat treatment. It is a well known and commonly accepted fact that these properties are widely influenced by the character of the heat treatment. Essentials of proper treatment are, uniform temperature distribution, close temperature control, operation on proper time cycle, and a furnace atmosphere that causes a minimum of decarburization and oxidation, and it is of first importance that these conditions remain constant from day to day. Naturally, all heat sources do not fulfil these qualifications to an equal degree. In general, it may be said that those most nearly fulfilling them are the most expensive. Any cost analysis, therefore, that does not include a study of the effects of various heat sources on the quality of the product and properly credit the higher priced heat source with the improved quality resulting from its use, is incomplete.

In making such a cost analysis it is suggested that the difference in cost between the two heat sources in question be deter-

mined and converted into per cent of the cost of the finished product. This value indicates at once the per cent increase in quality necessary to compensate for the increased cost. An example will suffice. A cost analysis of certain dies used for making armature punchings showed that the cost of electric energy used for hardening and drawing averaged one-half of one per cent of the finished cost. No costs were available for heat treatment with oil, but we will assume such costs at one-half the electric. The increased cost is thus one-fourth of one per cent. We will asume that the average number of punchings produced by the oil heated die is two hundred thousand. Omitting all other factors in relative operating costs, it would thus be necessary for the electrically heated die to produce, on the average, an additional 500 punchings, or two hundred thousand five hundred, clearly not an impossible attainment.

Heat treatment of high grade products must be followed by a rigid inspection, and it naturally follows that the more faulty the heat treatment, the more thorough and costly this inspection must be. Such inspection costs should, therefore, be considered in determining heat treating costs.

Defective material must either be scrapped or given another heat treatment. Where such defects can be traced to improper heat treatment they must be assigned to the cost of heat treating. Such cost items as these are often overlooked in making a cost analysis, whereas, in many cases, they far exceed the cost of fuel used for heat treating.

2. Cost of Subsequent Cleaning Operations

The amount of scale and decarburized metal produced on the surface of the steel varies widely with different heat sources and different operating conditions. The cost of cleaning operations, such as pickling, sand blasting, scraping, wire brushing and grinding are thus widely influenced by the nature of the heat treatment and should be made a part of any general analysis of heat treating costs.

In heat treating a certain gear, one concern found that the saving in cleaning costs through the adoption of electric heat was equal to twice the total cost of electricity used for heating the gear.

The loss of metal due to oxidation in many annealing operations must also be given consideration. While the loss may appear

insignificant, it is in some cases equal to the cost of fuel used for annealing.

3. Cost of Subsequent Machining Operations

The speed and, consequently, the cost of machining, is influenced by the hardness of the parts being machined. The speed of automatic machines is determined by the safe cutting speed for the hardest parts. Wide variations in hardness will thus slow down the machining operations and increase the cost. Such variations in hardness are often the result of improper heat treatment and, consequently, the increased machining costs must be taken into consideration in correctly determining heat treating costs.

4. Maintenance of Furnace and Auxiliary Equipment—Interruptions

While every one will agree that this item of expense should be made a part of heat treating costs, there are very few plants that keep separate records of such expenses. Usually, furnace repairs are made by the maintenance and repair department and lumped into a general plant expense account. Since different heat sources and different furnace designs require widely varying amounts of upkeep, no heat treating costs are complete that do not include this item of expense.

Cost of maintaining auxiliary equipment, including pumps, blowers, annealing boxes, carburizing boxes, etc., must also form a part of heat treating costs. In this connection it is of interest to observe that while annealing boxes may be required with some forms of fuel, with another they may be entirely omitted. A saving from this source equal to the total cost of heat used for annealing has been realized in several sheet steel annealing furnaces.

While cost accounting can be set up that will accurately record maintenance costs, a much more important expense item in many cases, interruption and loss of production due to furnace failures, is very difficult to convert into dollars and cents. This difficulty, however, does not justify its omission from a heat treating cost analysis, and some estimate of such losses must be included if the costs are to be considered reliable.

5. Capital Investment, Depreciation, Obsolescence

Suitable percentages covering capital investment, depreciation and, in some cases, obsolescence, will naturally be included in

heat treating costs. These percentages should be applied not only to the furnaces but to all auxiliary equipment, including stacks, blowers, fans, transformers, instruments, annealing boxes, etc., and to the factory floor space occupied. A case was recently investigated where a bank of high priced electric furnaces required a smaller investment than oil fired furnaces on account of their great saving in floor space. This was largely due to the elimination of the annealing boxes which occupied a large amount of floor space.

6. Labor and Working Conditions

A study of labor costs should include not only direct heat treating labor but expense labor required for transporting materials to and from the heat treating department and also labor required in starting and operating furnaces. These items should be investigated, particularly since some furnaces, on account of their noise and their pollution and heating of the atmosphere, must be confined to a furnace room apart from the manufacturing space while others can be installed in the machine shop. With the latter, much of this expense labor is eliminated. The amount of furnace attendance required will also vary widely with the heat source used. In one plant the saving of this expense labor by installing the furnaces in the machine shop exceeded the total cost of fuel.

Working conditions around the furnaces affect heat treating costs, and, while difficult to capitalize, must, nevertheless, be given consideration. The health and morale of the heat treaters and, consequently, their usefulness, is greatly affected by atmospheric conditions in the heat treating room. Improved conditions mean greater usefulness and smaller labor turnover.

Another item of labor cost that requires investigation is the possibility of using less labor as well as less skilled labor, through the use of automatically controlled and automatically operated furnaces. Savings from this source have, in many cases, greatly exceeded the total cost of fuel.

In studying heat treating costs, one thing that should always be borne in mind is that any generalizations are to be avoided. The great diversity of conditions met in the heat treating field make it essential that costs be specific if any value can be attached to them. Each problem requires individual study.

The difficulty of making a cost analysis along the lines suggested in this paper have forced many manufacturers to be content with "half a story" and to base their conclusions on items of cost most readily obtainable, hence, the undue emphasis placed on relative first costs and relative fuel costs. Only in large manufacturing plants where repetition work is being done, can such costs be accurately obtained.

There is at present great need for a thorough and unprejudiced investigation which will assist manufacturers in more accurately determining the overall cost of heat treating. This prompts us to venture here the suggestion that the American Society for Steel Treating, with its desire for usefulness and its interest in the advancement of the science and art of heat treating, might well consider directing a study along these lines.

GEARING AS A MEDIUM OF INDUSTRIAL POWER TRANSMISSION

By O. N. Stone

Abstract

This paper discusses the essential points which should be given consideration by gear users from the standpoint of design, material and thermal treatments, when specifying conditions under which gears should be produced. The author brings out the importance of closer co-operation between the user and the producer of gearing which will enable better equipment to be produced by machinery manufacturers.

IN discussing the subject of gearing as a medium of power transmission, the author will not enter into a theoretical discussion of the best tooth-form for a given purpose, or the type of machine to cut a gear, or upon any of the numerous technical phases of gear construction and design. The purpose of this paper is to bring to attention the general details requiring consideration by the gear manufacturer.

The present advanced art of producing gear teeth has been—like most other mechanical developments—a gradual evolution from primitive beginnings. We find that as early as 350 B. C., Aristotle, in one of his works on mechanics, indicates that he knew of toothed wheels. For a considerable period of time, gear teeth were nothing but "cogs" of indeterminate form. Somewhat later a few engineers found it desirable to give these cogs some particular shape, in order to decrease the noise and increase the wearing qualities. However, it was many years before engineers and scientific men discovered that this problem was well worth the attention of the keenest minds. Without doubt, the early studies of scientists, in their efforts to produce theoretically correct gear teeth, were scoffed at in their day, and their work was looked upon by "practical men" as a dream and a waste of time. A few of them had vision and persistence, and to them we owe a debt of gratitude for their pioneer work.

A paper presented before the Winter Sectional Meeting of the Society: Cincinnati, January 15 and 16, 1925. The author, Orville N. Stone, member A. S. S. T., is assistant chief engineer, Van Dorn and Dutton Co., gear specialists, Cleveland.

We find that Willis, Herrmann, Olivier, McCord, Beal, Bilgram, Lewis, Grant, Gleason, Fellows, and Eberhardt devoted themselves to this science and the result was a succession of advances in the theory and practice of gear design. Gear teeth are not mere "cogs" now, but have the curves of their outlines mathematically determined and accurately developed by highly specialized machine tools.

Today a world without gearing is inconceivable. The construction of mechanical equipment in many instances would be impossible without the use of gears. The automobile of today, as an example, could not exist without them and modern machine tools are absolutely dependent on their use. This might well be said of the whole field of special machinery, upon which depends the industries of the world. The gearing of any machine, whether it is a locomotive, tractor, automobile, or machine tool, is as vital a factor to its successful operation as the prime mover or operator.

Types of Gears

From a commercial standpoint, gearing may be divided into three main groups, namely: gears for automotive requirements; gears for railway use; and gears for service to the industries. While a long discussion might be had on either one, this discussion will be confined to that of the industrial gear.

Gears serve numerous purposes in the capacity of eliminating slippage or loss of power, such as might occur with other methods of industrial power transmission involving friction wheels, belts or rope drives. The four principal purposes for industrial gearing are as follows:

1. To transmit power
2. To change speeds
3. To change the direction of rotation of any particular part
4. To change the point of application of the power which is being transmitted.

The question of gear design is one which must be given much consideration. The points that one man considers essential to good design may not be held in such favorable repute by other engineers. There are certain fundamental considerations of design, which must be taken into account to produce satisfactory gears. While

it may be possible without some of these features to turn out a partially satisfactory product, yet it must be realized that poor features naturally handicap and tend to slow up production.

The principal requirements of a well-designed gear are that it be of uniform section and have a tooth-form that will most readily meet the service requirements as to fiber-stress and loading. Machine manufacturers should cooperate with the various plants in which the gears may be manufactured so that the design may bear a close relationship to the methods used in producing the gears.

Method of Mounting Gears

In designing gears careful attention must be given to the method of mounting. The best gear that can be produced will not give satisfaction unless properly mounted. Many noisy gears would not be noisy if installed with quiet bearings. The shafts should be stiff, the mountings rigid, and the bearings as close to the center of load-application as possible. Satisfactory gears are judged by the sounds they make when in operation, and they cannot run quietly unless they are properly mounted.

In the past, too little attention has been given to the mounting of gears. The gear manufacturer desires to turn out a finished product which will perform in accordance with the customers' specifications, but gears must be given at least fair conditions under which to operate. Much time and energy can be saved by giving close consideration to design and method of mounting before the manufacturing work is undertaken. Machine manufacturers will save themselves much money and avoid misunderstandings by submitting their designs and assemblies of their gear requirements to the gear manufacturer for his study before placing contracts.

Materials

In the selection of the proper material for the well-designed gear, we must carefully analyze the application of the load to the gear and determine whether the duty is to be continuous or intermittent. Also, we must consider the wear on the gear teeth, as a gear with teeth that have their surfaces rough and not true to the proper tooth-form are very inefficient. If the gear is subjected to low stress and very little wear, we may consider the use of cast iron, bronze, soft steel, aluminum or non-metallic material.

Non-metallic materials, such as rawhide and the various impregnated duck products on the market, are approximately as strong as cast iron, and are utilized where the reduction in the amount of noise is the prime consideration.

In case the gear is subjected to great wear without severe stress or repeated impact, we may use hardened gears made of plain carbon steel. Where there are high stresses present, gears should be made from forgings of a suitable alloy steel.

Where the gear is to overcome severe impact and other high stresses but subjected to normal wear, it is preferable that we use a forged blank of a high grade alloy steel and oil-harden it.

With castings specified by the designer, the gear manufacturer is not confronted by any very serious problems. It is important, however, that the various sections be kept uniform in order to overcome shrinkage cracks, which are liable to occur when producing the casting at the foundry. This is especially true with steel castings. Liberal fillets should be provided.

In some cases cast iron is a better material for gears than cast steel. This is dependent on the service requirements, whether or not the desired strength can be obtained without increasing the weight. Cast iron gears are easier to cast, come out cleaner, and require less machining than cast steel gears. There are many places where cast iron gears will give perfectly satisfactory results, and where conditions are favorable this material is quite satisfactory. Many foundries do not seem to understand that the way to obtain a good grade of cast iron for gear purposes is to have the combined carbon high and in solution, thereby preventing the carbon from crystallizing out. By casting the metal so as to give the necessary chill will also aid in retaining a sufficient quantity of carbon in solution. With the above considerations, a gear can be produced having greater wearing qualities.

It should be realized that a point can be reached at which it would be impossible to machine the stock without annealing. Although some manufacturers are annealing their iron castings, it is desirable to keep the total carbon content within a range that will permit machining without previous annealing.

A good gear iron has a total carbon content of 3.00 per cent with 2.50 to 2.75 per cent of silicon. Such castings will have a scleroscope reading of about 35. The practice of add-

ing about 15 to 20 per cent steel to the cupola charge has been found to produce a much better gear. The addition of this steel increases the density of the iron and also its strength, imparting better wearing qualities on the gear teeth than are obtainable with ordinary cast iron.

Steel castings either of the plain carbon or alloy types are utilized in the manufacture of heavy gears for severe service. Small-sized gears may be cast within certain limitations but it is usually desirable to make gears having a diameter of less than 10 inches from forged blanks. Of course, there are small specialty shops where small steel gear blanks can be cast very successfully. Plain carbon steels are used as a rule for gear castings of medium size. This is due to the fact that the alloy steels are more difficult to cast. For the past 10 years purchasers and manufacturers have been giving increased consideration to the heat treatment of steel castings. Many gear manufacturers do not anneal their cast steel gears of the smaller sizes. It is, however, desirable that all steel castings be properly annealed previous to the machining operations. This is one way to overcome the possibility of having a coarse granular structure in the gear teeth, which has been found to be quite detrimental to the life of the gear in service.

The field of the forged steel blank both in the hand- and drop-forged class has for the past decade been increasing steadily until at the present time we find a large percentage of gear users specifying that their gears shall be made from forged steel blanks. The field for the forged gear blank is much greater than at present, and with a closer cooperation between the forgeman and the heat treater, better gears will be produced than has been the case in the past. The principal reason for giving preference to the forged blank is from the standpoint of economy. This statement may be substantiated by the following facts:

1. Each and every blank can be relied upon to be converted into a finished gear. Hidden blow holes, such as may be found in castings, will not be found after expensive tool work has been done on the blanks.

2. Entire freedom from sand spots and chilled surfaces which in turn cause excessive tool wear and in many cases tool breakage.

3. A greater refinement in the structure of the metal.

The forging of gear blanks presents a problem with many

considerations. The temperature at the beginning and end of the forging operation should be held within certain well defined limits, according to the forging temperatures of the steels being used. Overheated gears are produced by excessive temperatures and can be used only after an expensive corrective treatment has been employed. Burnt gear blanks can never be properly reclaimed.

In case too low a finishing temperature has been used, the result is a cold strain which when relieved in heat treatment may reveal cracks, seams and fissures.

As a general rule, the flow lines of the metal in a forging should be at right angles to the forces applied to the gear teeth while in operation. It is evident, then, that a flat gear blank can be produced under a drop hammer, while those in which length is the predominating feature can best be produced by a forging machine. The size of the hammer has an important bearing on the problem. A large blank cannot be satisfactorily forged under a light hammer, because the time required to close the dies permits the blank to cool, and results in too low a finishing temperature.

Assuming that the forging of the blanks has been handled in a satisfactory manner, the next step is the preliminary heat treatment of the forgings previous to the machining operations. This initial treatment should not only place the blanks in a machinable condition but in the case of gears subjected to great stress, should relieve the distortion which is liable to occur after hardening. With the mild steels, this initial treatment consists simply of a short annealing or normalizing which removes most of the stresses which have been set up and renders the forgings suitable for machining. On the alloy and higher carbon steels, however, this is insufficient. Gear blanks of these steels should be normalized and cooled slowly or should be first quenched from a suitable temperature and then tempered sufficiently to enable them to be machined.

Heat Treatment

In the thermal treatment of the gears we have two general classifications to consider—case hardening and oil hardening. There are differences of opinion in the production of gears as to whether the case hardened or oil hardened gear is the best. As mentioned previously, when the gear is to be subjected to great wear without severe stress or repeated impact, case hardened gears

should be used. Case hardening may be accomplished in any one of three ways; by pack carburizing, liquid carburizing or gas carburizing. The methods employed in each of these processes are well known. Plain carbon steels are used extensively in the case hardened form but not for the more severe kinds of service because of the low tensile strength of the core. With a carbon content of 0.10 to 0.20 per cent and preferably 0.17 per cent, 70,000 pounds per square inch represents a good average value. Of course, it is understood that accurate tensile tests cannot be made of case hardened products and any values given are only approximations. With the use of straight carbon steel, not only is the tensile strength low, but the case is much more likely to spall off under heavy service than when an alloy steel is used. The type of alloy steel used depends upon the load-carrying capacities required and the desired physical properties.

Time Required for Carburizing

It is recognized that low temperature carburizing gives as efficient results as carburizing at high temperatures, and that the added time necessary to carburize at low temperatures is more than offset by the saving in fuel, furnaces, containers, carburizing compound and life of the finished article. Also the final heat treatment is more simple to perform if the carburizing has been done at a lower temperature. If brittleness in the finished product is a minor consideration, we may use a high carburizing temperature, but as a general rule the best results with gears are obtained by the use of a lower and uniformly regulated temperature.

There are various treatments that are advisable after the carburizing operation has been completed. After being held at the carburizing temperature for the required time to produce the necessary depth of case, the grain-size of the case and core of the gear has been enlarged due to the long soaking at high temperature. The excess carbide present will form a network between the grains or will separate in large masses if cooled slowly. If quenched in oil from the carburizing temperature while this excess carbide is in solution, the carbides will precipitate in extremely fine particles and will not have time to separate between the grains. This quench will also have a hardening effect upon the core, whereas a ductile core is desired. The disadvantages are that it does not have any refining action upon the coarse-grained core; that the

proper quenching temperature for the core is below the usual carburizing temperature; and that large blanks are difficult to handle on account of the heat. For this reason quenching directly from the carburizing box should be avoided except in cases where a hard surface is desired and low strength and toughness of core is sufficient. The usual practice is to allow the gears to cool in the box and then reheat them to a temperature which will refine the core and also break up any undesirable structures of cementite. Good results may be obtained by a single quench. In the single quench the core is refined but not the case.

For the best results a double quench is desirable—the first at a temperature sufficiently high to refine the core, and the second at a lower temperature to refine the case. This final quench may be in oil or water according to the type of steel. After the final hardening, the gears should be tempered to relieve the hardening strains and secure increased toughness.

The life of a case hardened gear is determined by the time required for the wearing down of the case to the core, at any point. Likewise if the case cracks it will flake off and thus the gear is useless. As a rule the actual cost of case hardening runs slightly higher than that of oil hardening.

The relative merits of case hardened and oil hardened gears is one which is receiving a great amount of attention by gear users. From our experience we find that the tendency at the present time is to use the oil hardened gear. As a general rule the oil hardened gear can be counted on for a steady uniform wear. In the past, the oil hardened gear was severely criticized on account of pitted tooth surfaces which were found after limited service. Today, with the steel mills manufacturing a higher quality material and with the improvements in the science of heat treatment, an oil treated product can be made which withstands the most severe service.

Alloy Steels

The leading role in the increasing rapid advancement of steel in the industries has been played by the principal alloys, such as nickel, chromium, vanadium, molybdenum, etc. These, while of great importance in themselves, have been strongly supported by improved methods of manufacture, together with a great accumulation of knowledge of the principles and practice of their improve-

ment by thermal treatment. The high stress demands of present day constructions are such that many of them could not possibly be met by a material other than a heat treated alloy steel.

Many alloy steels in the higher carbon contents are available for oil hardened gears, such as the straight nickel steels, the chromium-nickel steels, the straight chromium steels, and many other alloys containing combinations of tungsten with or without nickel, chromium, vanadium, etc. Each of these alloys have their merits, but for the general conditions we find that a gear made of a straight chromium steel when properly heat treated gives splendid results. This material is well adapted for forging and if properly annealed, machines very satisfactorily.

In the annealing of gear blanks made from this alloy steel, a spheroidized cementite structure is desirable. Annealing is carried on in a continuous furnace approximately thirty feet long and is done in a cycle of three stages. In the first stage the blanks are thoroughly heated to a temperature of 1550 degrees Fahr. and then cooled quite rapidly to about 1200 degrees Fahr. They are then reheated to 1300 degrees Fahr. and cooled in air away from all drafts and moisture. This leaves the blanks with a Brinell hardness of 196 to 207, without the presence of free ferrite in masses, allowing a maximum rate of cutting speeds on all operations, with the least amount of tool wear.

This alloy steel also has the advantage of possessing a wide temperature range for the heat treating process and is not subject to excessive warpage. After a final temper this alloy has a hardness sufficiently high to withstand heavy tooth pressures without pitting. The Brinell hardness obtained ranges from 512 to 555. It is well known that the presence of chromium in a steel has a refining influence on the grain and prevents to a large extent the development of the so-called crystalline structure. It likewise raises the critical points and reduces the rate of change in the critical ranges, thus enabling the steel to acquire a greater hardness without increased brittleness. This chromium steel has the characteristic fineness of structure which results in toughness without loss of ductility, resulting in greater resistance to wear.

Conclusion

As previously mentioned, satisfactory gears are often judged by their sound when running. No doubt many of us in passing

a set of gears in operation have heard a vibrant clatter and clash as though they were attempting to imitate a blacksmith shop. This is one of the most objectionable and inefficient conditions which can exist in a gear train.

A prime essential in mechanical efficiency is lubrication and this is especially true of efficient gear operation. Friction cannot be eliminated by even the most scientific efforts in gear design. When gears are in mesh there must occur a certain amount of sliding and rolling friction, and pure rolling friction is a scientific ideal that is rarely obtained in practice. A noisy set of gears indicates imperfect mesh, which is the greatest cause of wear. Repeated impacts cause vibration which is an objectionable condition. The progressive manager, superintendent and engineer today fully realizes the importance of gear lubrication which results in one of the most vital factors—gear preservation. Therefore, it can be said that gear lubrication is as important a problem as any other phase of industrial plant lubrication.

In closing, the author desires to leave with you the thought that better gears can be produced by gear specialists if we all use our efforts for closer cooperation. This in turn will mean that better equipment can be produced by the machinery manufacturers.

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

FUELS AND FURNACES FOR HEAT TREATING

By W. Trinks

Abstract

In this paper are discussed three classes of fuel, gaseous, liquid and solid, in addition to electrical energy. The advantages and disadvantages of each fuel used for heat treating are given. The proper selection of a fuel depends not only upon the B. T. U. content, but to a greater extent upon the form value of the fuel and the quality of the heated product.

The author describes the methods of recuperation, preheating and the compensating or counter-flow principle used for salvaging heat. Methods of heat transfer include salt and lead baths, muffle furnaces, and open chamber furnaces. Batch type and continuous furnaces for handling materials are discussed as well as various types of conveyors and hearths. Methods of heat application are also covered.

FUELS and furnaces cover a wide field of application. Many books have been written on this phase of industry without doing the subject justice in its entirety. That being so, you will realize that it is utterly impossible to treat the subject adequately in one paper. The author will, for that reason, limit himself to the application of fuels and furnaces in the field of steel treating. This latter term is rather broad, because heat treating includes processes which are carried out over several temperature ranges. For certain operations, such as blueing and tempering, a temperature between 600 and 1000 degrees Fahr. (315-540 degrees Cent.) is needed. For tempering after quenching, temperatures between 1000 and 1200 degrees Fahr. (540-650 degrees Cent.) are pre-

A paper by W. Trinks, professor of mechanical engineering, Carnegie Institute of Technology, Pittsburgh. This paper was given before the Cleveland chapter's night course given under the direction of Professor H. M. Boylston, Case School of Applied Science.

scribed. For quenching we need temperatures around 1400 degrees Fahr. (760 degrees Cent.). Annealing is carried on at a temperature around 1600 degrees Fahr. (870 degrees Cent.). Still other operations, such as carburizing, require temperatures between 1700 and 1800 degrees Fahr. (925-980 degrees Cent.). Pressing and bending of sheets and plates are done at temperatures around 1900 degrees Fahr. (1038 degrees Cent.). For rolling and forging, steel is heated to 2200 degrees Fahr. (1205 degrees Cent.). If heavy pieces that have to go through a series of operations are to be finished in one heat, their temperature is raised as high as 2350 degrees Fahr. (1287 degrees Cent.). Slabs and ingots for sheets and plates are heated to 2400 degrees Fahr. (1315 degrees Cent.) for the purpose of welding up blow-holes.

While the term steel treating covers all of these temperature ranges, we will consider more specifically furnaces for the temperature range between 1100 degrees Fahr. and 1400 degrees Fahr. (595-760 degrees Cent.), with occasional reference to the other temperatures. Fuels and furnaces are not an end in themselves; they are only tools that assist in heat treating. Let us consider the fuels first.

Fuels

In the list of fuels we have three groups, gaseous fuels, liquid fuels, and solid fuels. In this list, electrical energy stands in a group by itself. It is not a fuel, but it is a source of heat energy which, as far as our purposes are concerned, takes the place of fuel.

Electrical Energy	Gaseous Fuels		Liquid Fuels	Solid Fuel	
	Natural	City	Kerosene	Anthracite coal	On the grate
	Coke oven	Raw producer	Light fuel oil	Bituminous coal	On the grate
	Carbo	Clean producer	Heavy fuel oil	Coke	On the grate
	Water	Blast furnace	Tar	Wood	
	Oil	.....	....	Powdered coal	

Strictly speaking, we should include tar oil in this list, but it is not of as much importance in this country as it is in England and in Germany. Tar oil is a very light oil, which is made from low temperature carbonization of coal.

We will review this list and eliminate those fuels, the use of which is not commercially feasible.

Blast furnace gas is not used except in a few steel plants; therefore it does not enter into our consideration. Coke oven gas is likewise used only in steel plants and in shops that work in conjunction with steel plants. Raw producer gas is useful for rough mass-heating, more particularly for forging and rolling purposes. Its use is not increasing, because in steel plants where much rough heating and open hearth melting is done, we try to replace it by coke oven gas and tar. For average heat treating we eliminate it from our list, leaving natural gas, city gas, clean producer gas, water gas, carbo gas, and oil gas. Carbo gas is a mixture of clean producer gas made from coke and of distillation gases. If coal, going to a gas producer, is heated gradually, the volatile matter is driven off before the coal enters the producer. That volatile matter consists partly of vapors and partly of gases. The vapors can be condensed and the gases can be mixed with the clean producer gas which is made from the remaining coke. The mixture, in this country, is known as carbo gas. While carbo gas is a desirable fuel, the gasifier installation is so expensive that most of us will not have to worry about that gas for some time to come. This elimination leaves natural gas, city gas, water gas, clean producer gas, and oil gas.

Although the gasification of fuel oil and the production of an oil gas have been tried repeatedly with but little success, "oil gas" in its present form is something brand new. A concern in New Jersey has produced a gasifier, or, better said, a vaporizer, which is no larger than a good sized alarm clock. A light oil, and a few per cent of the air required for combustion combine on a hot spot and produce a mixture of oil gas and oil vapor which burns just like natural gas or manufactured gas. The small size of the gasifier allows it to be located close to the furnace, so that condensation of the oil vapor is obviated. For the present we can eliminate oil gas, because the use of the gasifier will be limited until the sales price is low enough to warrant its general adoption. In consequence, we need consider only natural gas, manufactured (city) gas, clean producer gas, and water gas.

In a similar manner we can reduce the list of liquid fuels. Gasoline and kerosene drop out because they cost too much and do not offer advantages that are commensurate with the cost. Tar is also out because it is a by-product of the coke works, which

is usually attached to a steel plant, and because it is burned directly in the steel plant or sold for manufacturing purposes. It is a dirty fuel and has the disagreeable property of depositing solid coke if heated to a high temperature, and makes a large amount of black smoke if the temperature is too low.

As a result of this elimination we need concern ourselves with one liquid fuel only, and that is fuel oil.

From the list of solid fuels, we can eliminate anthracite and wood, because they can be had in a few places only. Bituminous coal and coke are burned "on the grate," but the number of furnaces using fuel in that manner is decreasing. Remarkably good heating has been done by burning coal or coke on the grate, but the attaining of that objective presumes skill not only in design but more so in operation. And as long as more convenient fuels which produce good results without the exercise of so much skill and care are available, manufacturers are not willing to pay high wages for skill in burning coal on the grate. In consequence we can, in the great majority of cases, eliminate coal and coke on the grate for steel treating purposes.

Powdered coal is a useful fuel for rough work. It is not a useful fuel for precise work because powdered coal carries ash, and the ashes are deposited on the work which is being heated. Moreover, powdered coal is a fuel for large plants, because the preparation of powdered coal is extremely expensive in a small plant. It is still better for cement kilns, because the ashes make more cement, but, unfortunately, the ashes make neither more nor better steel. For that reason the steel treater will not have to concern himself about powdered coal for some time. Some day a genius may come along and make a small unit-pulverizer which produces a uniformly fine powder, and does it consistently. It is true that we can buy unit-pulverizers now and that they give us a reasonably fine powder when they are new, but after they have been running for two or three months, the powder is coarse.

After this process of elimination we have only a few fuels left, namely, natural gas, city gas, water gas, clean producer gas, light fuel oil, heavy fuel oil. We have come down to six fuels and to electrical energy. Each one has its field of application, and the problem is to find the right fuel for the right job. This problem is one of the items that we shall discuss in this paper.

Let us investigate the development in a chronological or historical order. Eight to ten years ago, natural gas and fuel oil were the standard fuels for the treating of medium sized steel pieces. For small work, such as small tools, city gas could compete with the other fuels. In those days the usefulness of fuels was judged almost entirely by the cost per B.t.u. A gallon of fuel oil has a heating value of about 140,000 B.t.u. If we pay 8 cents a gallon, then we get about 18,000 B.t.u. for one cent. Natural gas has a heating value of 1000 B.t.u. per cubic foot and in many localities costs 50 cents per 1000 cubic feet. We get, therefore, 1,000,000 B.t.u. for 50 cents; for one cent we get 20,000 B.t.u. We see that per B.t.u. these two fuels are close together in cost. Now let us compute the B.t.u. cost of city gas. It has in the neighborhood of 500 B.t.u. per cubic foot. We pay one dollar per thousand cubic feet. Then we get 500 × 1000 for 100 cents, or for one cent we get 5000 B.t.u. A commonly drawn conclusion was that city gas was too costly, being four times the price of the other two fuels. Therefore, steel treaters figured that natural gas and fuel oils were the fuels to use, except for small and precise work.

Then came electricity as a source of heat energy. When the propaganda for the electrically heated furnace began, the builders of oil-fired furnaces and of gas-fired furnaces sat back and smiled. They reasoned that electricity as a source of heat energy would never interfere with their business. Let us follow their method of reasoning. "If you get one kilowatt hour of electric power for one cent, you enjoy a very low rate. Most of us pay 5 or 10 cents. But one kilowatt hour equals 3400 B.t.u. In other words, we get 3400 B.t.u. for one cent. Since city gas has not been able to make much headway at 5000 B.t.u. for one cent, then why should electricity, which delivers only 3400 B.t.u. for one cent, give us any concern?" On the other hand the manufacturers of electrical equipment said, "It is not the cost of the fuel that counts. It is the ultimate cost of perfectly heated and finished product that counts. If electricity were four or five times as expensive as it is now, and heated material without any scaling or any rejections, it would be cheap compared to any fuel, if that fuel resulted in scaled, pitted, burned work, with hard spots—material of which one-half would have to be thrown away." On the basis of this reasoning a new term was introduced in fuel tech-

nology. It is the term "form value." It has been used in some of the commercial literature for quite a number of years, and means the value which the form of the heat energy has in contradistinction to the B.t.u. which we get for one cent. The latter furnishes, at best, only a crude comparison, because it does not represent the heat which we can put into the steel for one cent. With fuels, the available heat is only a small fraction of the potential heat in the fuel. In the case of electrical heating, the available heat, that is to say, the heat which we put into the steel is a large fraction of the delivered energy, because electricity is an energy of a high class. Like light, it is one of the highest forms of energy which we have, a form of energy which can be converted into heat without any loss. To use a simile, it can be bottled up. Electricity can be converted into heat in such a manner that almost all of it can stay in the furnace and practically none has to be taken out. With fuels it is quite different. With them, we must make the heat in the furnace by combustion and allow the products of combustion to escape. We cannot do like the inventor of a certain steam turbine which, in his opinion, used so little steam that it did not need an exhaust. It would be great if we could do the same trick with fuel-fired furnaces, but, of course, we must let the gases out, and they take a large amount of heat with them. If we could extract all the heat from the flue gases and put it into the steel we would save a great deal of fuel, and this is what a good many furnace engineers try to do by the use of recuperators or regenerators. We can also use the heat of the flue gases for preheating the steel, but as soon as the furnace builders use any of the heat saving devices their sales departments get into difficulties because they cost money. When people buy fuel-fired furnaces they seem to prefer the simplest possible furnace—a space surrounded by four walls, covered by a roof and equipped with a burner to produce heat. It is difficult to induce furnace purchasers to pay for high class equipment as long as fuel is cheap. The slogan is, "Reliability first, economy second." And since the cost of fuel is always a small fraction of the total cost of heating, little or no attention was paid to fuel saving. It was not until the prophets of the electric furnace came around and pointed out what could be done with electricity that the builders of fuel-fired furnaces began to wake up to the situation. The author holds no

brief for electrical heating, but we are forced to admit certain advantages which this form of energy offers us.

Among the advantages, two stand out prominently. One is comfort of the workmen. You can have any electrically heated furnace in the plant without suffering any discomfort from heat, because the cost of electrical energy is so high that most excellent heat insulation pays well. Especially in the summer, working around an electrically heated furnace is more pleasant than working around a fuel-fired furnace. In addition, it is to be noted that the electrically heated furnace discharges no fumes. It needs no stack. The second advantage is that an electrically heated furnace can be put in any place which can be reached with a cable, and a cable is easily run almost anywhere. The result is that the furnace can readily be placed directly in the path of manufacture. If the process of manufacturing requires a forging machine, a lathe, a planer, a milling machine, heat treating and quenching equipment, grinding and finishing machines, all of this equipment can be laid out in a continuous straight line. And if a change in the layout is required, the furnace can easily be placed where it is needed. There are no gas or oil mains and no stacks. There is no regenerator which causes the furnace to become part of the building. We could never relocate a regenerative furnace without a complete rebuilding. Summing up, we have advantages in the electric furnace which no fuel-fired furnace can offer, namely, a small amount of radiated heat, the absence of fumes, and semi-portability.

In the comparison of fuels and furnaces, the term "thermal efficiency" is often used. By thermal efficiency in furnace work we mean the ratio

$$\frac{\text{heat in steel}}{\text{heat in energy}}.$$

We have used the word "energy" instead of fuel in the denominator because we have to include electricity. The thermal efficiency for fuel-fired furnaces, particularly for oil-fired furnaces, is frequently as low as 15 per cent. For electrically heated furnaces it averages 75 per cent. The ratio is one to five, approximately. Reference has already been made to the fact that with electricity we get 3400 B.t.u. for one cent and that with oil we get 18,000.

But with oil, the valuable heat is only ⅕ of that value in comparison to electricity; dividing 18,000 by 5 we get 3600 available B.t.u. for one cent. We see that on the basis of available heat it is almost a stand-off unless we can buy oil very cheaply, for 3½ to 5 cents, or thereabouts, per gallon, or else build better oil-fired furnaces. However, steel treaters do not pay as much attention to thermal efficiency now as they did in former years. In this connection it is significant that a good many firms which six years ago had no thought of building electrically heated furnaces are not only building them now, but are making a specialty of furnaces of this type. There are conditions under which nobody would think of using electric heat. Take, for instance, the heating furnaces in a steel plant. Let us consider an average steel plant making 100,000 tons of steel per month, and let the blooms be reheated; then if it were desired to heat the steel electrically it would be necessary to build a power plant of more than 50,000 kilowatt capacity for heating the steel, whereas the whole plant now uses only 15,000 kilowatts for rolling and all auxiliary machinery. Besides, a steel plant has so much waste fuel in the shape of coke breeze, tar, coke oven gas and blast furnace gas that there is no need for thinking of any other source of heat energy. For that reason, electrical heat will not make any headway in such plants except, perhaps, for a few soaking pits.

We mentioned the fact that many fuel-fired furnaces have a thermal efficiency of only 15 per cent. On the other hand, the author has seen fuel-fired furnaces, particularly gas-fired furnaces, having an efficiency of 60 per cent when burning natural gas, city gas, or by-product gas. The manner in which high efficiency is obtained will be discussed under furnaces. If we can run a furnace on natural gas with an efficiency of 60 per cent, then we are away ahead of electricity, provided we produce just as good heating. If city gas is used with 60 per cent efficiency and electricity with 75 per cent, then the cost ratio would be as 4 to 5. That is to say, we would get 4000 B.t.u. useful heat as compared to 3400 B.t.u. with electricity and would be ahead quite a little if we used city gas. As a matter of fact, one of the great problems in the fuel field is now whether it is better to use city gas or electricity. In this connection it is interesting to note that both city gas and electricity are sold by public utilities, and it makes little difference

to the latter which of the two they sell. It is all the same to them whether the money comes to them through the sale of electricity or of city gas. On the other hand, it makes a lot of difference to the equipment manufacturer. And thus we find that there exists quite a strenuous competition between city gas and electricity. If we review an electrical trade paper we will find that electricity is very much better than gas. If we review a gas journal we will find that gas is very much better than electricity.

In order to become thoroughly posted on this subject, a concern making automotive equipment made a very elaborate test. That concern put electrically heated furnaces and gas-fired furnaces side by side, doing the same work in the heat treating of small parts. The product was inspected closely for the purpose of determining the superiority of one energy over the other. Furnace capacity, fuel costs, and labor costs were also compared. It was found that, in the plant in question, the cost of electricity was to the fuel cost for gas as 5 is to 3. With regard to the production in eight hours and the men required to handle the furnaces, it was found that the labor cost of the electrically heated furnace was to the labor cost of the gas heated furnace as 5 to 4. On the strength of these comparisons, additional gas-heated furnaces were installed. In that particular place it paid to use city gas.

You will wonder why the author pays so much attention to the two kinds of energy sold by public utilities corporations. The reason is that these two sources of heat energy offer a great advantage, which is this: We open a valve or close a switch and the energy is there, and, moreover, it is the same today as it will be tomorrow and as it was yesterday. The public utilities corporations are carefully watching the voltage of their electric current and the composition of their gas. The law prescribes to them certain limitations within which they must stay, and that is important. If we wish to have good temperature control and atmosphere control in a furnace we must have the same quality of gas, or the same composition continuously. We will discuss that point a little more in detail later on. Electricity is, of course, always the same, with the result that temperature control works well.

With oil, on the other hand, several difficulties exist in securing good furnace control. We may have purchased a certain brand

of oil; then an interference with transportation occurs and we must buy a different oil. One day we get 24 degrees Baumè oil and the next day perhaps 34 degrees Baumè. The degree Baumè, as you know, is a measure of the specific gravity of oil and, indirectly, of the viscosity. But if the viscosity changes, it means new adjustments all around, because, with a given setting of the temperature control, with a given setting of the oil heater, and a given oil, there will be correct atomization and good temperature control, but as soon as the oil changes, these are all off. We must adjust the heaters, adjust the pumps, adjust the burners, and in the meantime we spoil a good deal of valuable material in the furnaces. While this looks bad for oil, these troubles need not necessarily occur. If the purchaser has much foresight, he will install a good sized storage tank and always keep a large quantity of oil on the premises; in that case the composition of the oil can be kept constant in spite of transportation difficulties. If oil is to be a good fuel for heat treating, additional precautions must be observed. Oil strainers must be kept in excellent condition and the oil heater must function properly. With oil, just as good results can be obtained in heat treating as with city gas or with electricity, but greater skill, greater care, and eternal vigilance are required. This same thought can be carried to a logical conclusion. There are men who can heat treat with coke on the grate just as well as with electricity, but it requires still greater skill than oil does. It is unfortunately true that it is harder every day to find that skill. As a matter of fact, heating with coal or coke is fast becoming a lost art. This fact may, in part, be due to the physical exertion which the shoveling of coal or coke requires.

The fuel cost for heat treating is frequently less than one per cent of the total cost of the finished article. For very light parts it is less than $\frac{1}{5}$ of one per cent. In view of this fact, it is no wonder that fuel costs are considered an unimportant item and that convenience and certainty of results are given greater weight. It is the convenience and the comfort of not having to labor with uncertainties that have made city gas and electricity desirable sources of heat energy for steel treating.

In a few plants water gas, or clean producer gas is used. Either gas requires an expensive installation. In a large plant

—such as that of the Ford Motor Company—either water gas or clean producer gas can be used profitably, because the cost of a given amount of heat is much less than that of electricity or city gas, and because the large size of the plant renders careful operation possible. As a matter of fact, we find clean producer gas used at the Highland Park plant of the Ford Motor Company. In the same plant there are used oil, coke oven gas and electricity, the latter on an increasing scale. Oil is used principally as an emergency fuel when the supply of coke oven gas fails; at other times its use is limited. As previously mentioned, clean producer gas and water gas require a large plant, which must be carefully operated. To that end, several men and an engineer must spend their whole time in the running of the gas plant. The labor can be reduced if a considerable amount of automatic apparatus is provided; but even automatic apparatus must be kept up and supervised. It is just like having a city gas plant in your own organization with this difference, that we can shut off city gas when we have finished and do not have to worry about what happens. In a comparatively small plant, if there is an interruption of operation at one furnace, it probably affects the whole plant, and the whole apparatus has to slow down. When we make the gas in our own plant we save a great deal in the cost of fuel, provided that the whole outfit is big enough to run steadily at the same heat, so that the reduction of fuel cost is not counteracted by increased labor cost and by variations in the composition of the gas, which latter mean spoiled and rejected material. Summing up, we find today an ever increasing tendency to use city gas and electricity in small heat treating plants. The oil-fired furnace is still holding its own, but it is not increasing as rapidly as formerly, because oil offers difficulties on account of change in quality, change in viscosity, and because of suspended solids. What good does it do to install the finest possible oil burner and temperature control if all at once the flame begins to sputter and becomes irregular, because a piece of dirt that was in the oil has clogged the fine orifice in the regulating valve? Those who have heated with oil will bear witness to the fact that these are some of the trials and tribulations of the heater when he uses oil. This fuel usually contains finely divided suspended matter which should be taken out by strainers or scrubbers. Good operation of an oil-fired furnace depends upon the auxiliary equipment. If it is kept in ex-

cellent shape, oil can be used to good advantage. In large plants, clean producer gas and water gas are useful, if the gas generating equipment is carefully operated.

Furnaces

We shall compare furnaces with regard to the utilization of waste heat, with regard to the method of heat transfer, the method of material handling, and with regard to the method of heat application. Other problems should be considered, for instance, the various combustion devices, the methods of converting electrical energy into heat, temperature control, and control of furnace atmosphere. However, one paper cannot be made long enough for all of them, although they enter distinctly into the problem of steel treating.

With regard to the utilization of waste heat we can be rather brief. In electrical heating there is hardly any waste heat, except in annealing. The heat which is in the steel as it comes out of the furnace is the useful heat, if the steel is to be quenched, but if the steel is to be brought up to a high temperature slowly and brought down again slowly to room temperature, then all the heat which was imparted to the steel is waste heat, and should be utilized. This thought has given rise to a type of annealing furnace which is known as the regenerative, counter-flow, or compensating type.

Suppose that in a long tunnel furnace or channel furnace there are two trains of material passing through in opposite directions. Suppose that the walls of this furnace are heat tight and that we heat the center section electrically, which creates a hot zone. Then the material which goes out in either direction will radiate and otherwise communicate heat to the walls and to the incoming material. The latter will be heated gradually by the outgoing charge; the longer the furnace (if it is heat-tight), the more complete will be the heat interchange. If the furnace is long enough, the outgoing material will emerge at room temperature, and the incoming material will be preheated almost to the correct temperature by the time it reaches the hot zone, and we will have to supply only a very small amount of heat. For annealing work that type of furnace, as previously mentioned, is gaining in favor. Evidently, it is useful only for annealing and not for quenching.

It is, furthermore, limited to the annealing of regular shapes in regular production. It will not do for occasional work.

The compensating principle is not limited to electrically heated furnaces. On the contrary, it has been successfully applied to fuel-fired furnaces which, in that case, bear the name of tunnel-kilns, or channel furnaces. In them we can salvage not only the heat of the annealed material, but also a large part of the heat in the products of combustion. At the present time, this type of furnace is found mainly in sheet mills, although it is successfully used for annealing other material. Mention has already been made of the fact that the compensating principle furnishes the only method which we have of utilizing waste heat in electrically heated furnaces. But in furnaces fired by fuel, whether it be gas or oil, city gas or natural gas, we meet the problem of what to do with the hot products of combustion, the heat of which constitutes a serious loss. Furnace engineers are trying their best to salvage that heat. Their efforts have given rise to waste heat boilers, recuperators, regenerators and the preheating of the stock itself in a continuous furnace; that is, a furnace in which the material always comes in at one end and moves through to the other end, whereas the combustion takes place at the discharge end. After the piece has been heated it is pushed out through the side of the furnace or else it drops out at the end. Combustion takes place at the hot end, and the products of combustion leave at the cold end. The continuous furnace affords a good method of utilizing waste heat, which method is used wherever possible. It has two additional advantages. One is the gradual preheating of the material. The material moves gradually from a cool zone into a hotter zone and there is little danger of overheating. Second, it has the great advantage of saving labor. The cold material is placed on a conveyor, is pushed into the furnace and drops out automatically at the other end. For all of these reasons the continuous furnace is popular.

Recuperators are a self-suggestive method of heat salvage. A recuperator is a device in which the outgoing flue gases transmit heat through a wall to the incoming air. The larger the extent of the heat-transmitting surface, the more heat is transmitted and the greater is the saving. For the sake of economy, there should be a recuperator on each fuel-fired furnace, but in practice, few are

used. This discrepancy is due to the fact that they are expensive and frequently cause trouble. Occasionally, a sharp flame will reach into the recuperator and burn it out or scale it, or crack it. In the past, there has been so much trouble with recuperators that most furnace owners have lost all faith in them. But a great deal of progress has been made by the introduction of new materials, such as the iron-chromium alloys. In addition, certain balanced-draft tile recuperators have been introduced. It now looks as if recuperators would come back to life again by the introduction of modern alloys, but the people who build fuel-fired furnaces with recuperators will have to hurry up as far as heat treatment is concerned; otherwise the electrically heated furnace may beat them to it.

If the furnace gases on their way out pass through brick checker work and if, later on, after the flow has been reversed, the combustion air passes through the same checker work, the furnace is said to be regenerative. In steel treating, regenerative furnaces are so little used that we need not spend much time on them. They are too cumbersome.

Method of Heat Transfer

The next subject in our discussion is the method of heat transfer. We speak of the direct-fired or oven type of furnace, of the semi-muffle type, the muffle furnace, and of salt or lead baths. Let us consider these types in the reverse order. When do we use a salt or lead bath? The purpose of lead or salt baths with the exception of cyanide baths is that of bringing out the material clean and perfectly free from scale. If it were not for that reason there would be no need for salt baths or lead baths. In the heat treating of fine tools we cannot afford to have any pitting or the slightest amount of scale. Salt and lead baths, therefore, are mainly used for tool work. There are people who believe that salt or lead baths are used because they insure a gradual transfer of heat to the work, but with those people the author takes issue, because he cannot think of any more severe heating than taking a fine tool that is quite cold and dipping it all into a bath of molten salt or lead. The heat transfer from the salt or lead bath to the sharp corners of that tool is much faster than it can possibly be in an oven type furnace. For that reason it is advisable to heat that tool first in an open chamber

furnace to about 850 or 900 degrees Fahr. (455-480 degrees Cent.). No perceptible scaling occurs below 900 degrees Fahr. When the tool has a uniform temperature of 900 degrees Fahr., plunge it into the salt or lead bath. With that procedure there is much less danger of losing a tool by cracking than if it were plunged cold into a heated salt bath or a lead bath.

Cyanide baths serve an additional purpose besides that of heating. Cyanide baths are used for the purpose of effecting a chemical change which consists of carburizing the outer layers of the steel. Carburizing can be done in an atmosphere of hydrocarbons, or in a hardening compound, or in a cyanide bath.

In addition to insuring freedom from scale, salt baths and lead baths offer an additional advantage. The object being heated is literally suspended in heat; the latter is flowing in from all sides. If we hang a piece of steel from a thin wire all by itself in a furnace, we get the same results as far as uniformity of heat transfer is concerned, but we are not so sure about the non-scaling atmosphere. Even in an electrically heated furnace some oxygen is present, and some scaling is produced.

The muffle type of furnace needs some discussion. The muffle causes a reasonably uniform heat transfer; it also is intended to produce a neutral or indifferent atmosphere around the material to be heated. In electrically heated furnaces the muffle serves to keep the charge away from the resistors, because if we push a tray full of steel into the furnace and have been a bit careless in piling it, a piece may roll off and strike the resistors, and then there are fireworks in the furnace, followed by a big repair bill. Therefore, some furnace men like a muffle, or at least a perforated muffle, in electrically heated furnaces.

While we speak of muffles and of their effect upon furnace atmosphere, we might mention that the problem of working with a correct furnace atmosphere is becoming more and more important, because furnace men have come to realize that, in order to prevent scaling, we must have a peculiar kind of furnace atmosphere. Air, as you know, consists of nitrogen and oxygen. Nitrogen does not affect the steel, but the oxygen produces scale. Now let us consider the effect of the products of combustion upon steel. They consist of nitrogen, water vapor, carbon monoxide, carbon dioxide, and occasionally sulphur dioxide. If there is excess of air or incomplete mixing, the furnace atmosphere contains

oxygen. For a long time it was believed that an atmosphere of nitrogen, water vapor, and carbon dioxide without even a trace of oxygen is perfectly neutral and does not produce scale, but we know now that such an atmosphere is not neutral. It has been found that if red hot steel is in contact with water vapor or with carbon dioxide, the gases break up or dissociate and the oxygen goes to the steel, producing scale. Therefore, the products of perfect combustion are not neutral or indifferent, but attack steel and scale it. It has also been found that the products of incomplete combustion containing several per cent of carbon monoxide exert a certain protective action. It has long been known by heaters in steel plants that, if they keep a very smoky flame, the steel will not scale nearly as much as it does when they have a clear furnace. How much carbon monoxide is necessary to protect the steel? It has been found that one per cent of carbon monoxide (CO) is the minimum which will have a protective influence and that three or four per cent CO exerts a fairly good protection, but even that amount does not guarantee perfect protection. The formation of hard scale is prevented if the fuel is burned with 10 to 15 per cent deficiency of air.

If steel is not to be quenched but only annealed, the heating can be done in a neutral atmosphere without difficulty, and a firm in Germany has recently brought out an electrically heated furnace which can either be filled with a neutral gas or else can be evacuated. In the latter case, the atmosphere cannot help being neutral, because there is no atmosphere. That firm uses electric resistors made of ordinary iron ribbon; they will not oxidize because there is no oxygen in the furnace gases. The iron ribbon has a high temperature coefficient; as the temperature rises, its resistance to the flow of current grows rapidly and no temperature control device is needed. The whole device is self-regulating.

The good effects of an atmosphere which is rich in carbon monoxide are not obtained without cost, because each per cent of carbon monoxide means 2.5 to 3 per cent loss in fuel. This condition explains the low efficiency of many oil or gas-fired furnaces from which a large amount of the fuel passes away only partly burned. This same situation also explains why recuperators burn out so rapidly; the gases, as they enter the recuperator, contain from 10 to 12 per cent of unburned fuel. The slightest air leak produces a small blowpipe flame that burns out the recuperator

when and where it strikes. This whole problem creates an unpleasant situation in fuel-fired furnaces: If we protect the steel we lose fuel. As a rule, the man who is responsible for the heating likes to work with a smoky flame. The city smoke inspector and the fuel engineer adjust the burners until there is no smoke, and combustion is nearly perfect, but as soon as their backs are turned the heater changes the burners back to produce a smoky flame.

If the furnace is to be filled with an inert gas, then it must be tight, and every trace of air must be removed. Doing so presents certain difficulties. In this respect the electric furnace has a certain advantage, because the same gas stays in all the time, or is at least supposed to do so. An accidental discovery taught us how to produce a non-scaling atmosphere in electrically heated furnaces. In one plant it was found that an unusually small amount of electrical energy was needed for heat treating the steel and that the steel came out quite clean. Everybody wondered why that happened, when the same type of furnace had never given such good results elsewhere. Then came this discovery. The pieces which were heated in that particular furnace came from a turret lathe and had a good film of oil on them. As soon as they were pushed into the furnace the oil vaporized; the oil vapor burned up the oxygen, producing much carbon monoxide. Besides, the combustion of the oil vapor produced heat and cut down the kilowatt hours. At the present time several works have adopted the expedient of spraying oil into electrically heated furnaces.

Most furnaces are built with an open chamber; that is to say, the products of combustion come in contact with the material to be heated. With gas fuels, this method of heat transfer is not so bad. With the proper system of combustion, and with an unvarying composition of the gas we can produce a good furnace atmosphere which contains the right amount of carbon monoxide (CO), and we can maintain it indefinitely. With oil fuel there is some difficulty. With oil the least little bit of change in viscosity or temperature in the oil will vary the atmosphere, whereas, with gas, conditions can be kept constant unless there is a change in the composition of the gas. And with city gas we are reasonably sure that there is no change in the composition of the

gas. For that reason, the open chamber is used in heat treating by gas fire more than the muffle type. If a muffle is used, then we should put something into the muffle to absorb the oxygen, for instance, powdered charcoal. The muffle has its limitations. At high temperatures the muffle walls become permeable to gases. The pores are opened up, as it were, so that the gases diffuse through the walls. Whenever we use muffles they should preferably be made of silicon carbide, because its mechanical strength is great and because it has seven to eight times the conductivity of ordinary fire clay. The ordinary fire clay muffle should be banished, because it is weak, cracks easily and is not a good conductor of heat.

Reference has already been made of the fact that in electrically heated furnaces the muffle serves the very good purpose of protecting the resistors from contact with the charge. On the other hand, a muffle wall means that the ribbon or other resistor must work at a considerably higher temperature than the inside of the muffle. So we see that the muffle furnace has disadvantages and advantages at the same time. The question is which of the two is greater. A compromise has recently been effected by using a muffle with a large number of small holes. The perforated muffle has the advantage of allowing heat to radiate through the small holes and yet it protects the resistor or the heating element against material falling against them and causing a burning out and damage to the electrical resistor.

Materials Handling

One of the subjects worthy of consideration is the method of handling materials in and through the furnace. With regard to the method of handling we speak of the "batch type" and of the "continuous type." In the batch type or in-and-out type, we lay the material on a hearth and pick it up from the same place where we put it down. A continuous furnace is a furnace in which the material enters at one end, keeps moving and comes out heated at the other end. In practice we find both types, and the question is when should we select one and when the other. For all small work, for occasional heating, for all "variety work" the batch type furnace is the correct one. It is much cheaper in first cost than the continuous type, takes up less room and adapts itself easily to a great variety of work. The batch type furnace is made

either with a fixed hearth or with a car bottom hearth. In the latter case the hearth rests on wheels or balls. The material to be heated is laid on a car; the car is rolled into the furnace, allowed to be heated, and then the car is pulled out. Now, the question is, when do we use the car bottom furnace in heat treating? It serves well whenever the material to be heated is too heavy and bulky to be handled through a furnace door. If, for instance, we have to heat treat a big steam turbine disc or shaft, a marine shaft, or a big casting for a ship, we could not pick up any of them with a pair of tongs and guide it into the furnace and, later on, lift it out again. It is necessary to have a crane above the piece and lift it up vertically. In this case we can do one of two things. We either lift the roof of the furnace and remove the piece with a crane, or we use a car. In one plant a whole furnace (cylindrical wall and dome-shaped roof) is lifted up and out of the way for the heat treating of rolls such as are used in rolling mills. However, that was a rather special case. More often if we have shafts or disks to heat they are placed on a car, heated, and removed from the furnace while lying on the car. They are then removed one by one by means of a crane and are quenched in oil or water. During the war, guns and ship shafts were heat treated in that manner at various works.

Material can be moved continuously through a furnace by several different methods. We find, for instance, the pusher type, the conveyor type, the rotating drum type, and the rotating hearth type. All of them are used in heat treating practice.

In the pusher type furnace the material is laid down outside of the furnace and is pushed through. One piece of material rests against the next one, a force is exerted at one end and is transmitted from piece to piece, moving all of them at the same time. If the material is of such shape that it cannot be conveniently pushed by transmitting the force directly to its neighbor, we frequently put the pieces on trays and push the trays through. Then when we wish to quench the charge the problem arises as to how to dump the charge into the oil without dumping the tray also. The problem has been solved in a rather ingenious manner. The tray has projecting lugs at the back end. The tray tilts and allows the charge to slide off, but the rear lugs hold the tray from going into the quenching tank. The tray is then lifted off and is brought back

to the charging end. On the way back it usually travels on rollers. The tray pusher type is popular for mass production in the heating of small articles. It is much used in automobile work. The heat in the tray is, of course, lost.

The chain conveyor type is popular with inventors but not quite so popular with the people who have to use it. In its commonest form it employs a chain which runs over sprockets; the whole chain may be in the furnace or it may be located outside of it. Again, it may be in the furnace on the heating travel, and outside on the return travel. The material is put on the chain at one end of the furnace and is delivered at the other end. A properly designed chain will carry steel of almost any shape through the furnace and dump it at the other end. However, chains are not free from troubles. If a chain gets hot, it expands. One part of the chain may become hotter than another and stretch more than the cooler part and "hang back." The cooler part does all the pulling and is stretched beyond the elastic limit. That causes binding and breaking of the chain after a short time. With great temperature differences, we may even have compression on one part of the chain, caused by excessive expansion and a tendency to buckle, while the same force tends to stretch and break another part of the chain. At red heat temperatures, chains scale rapidly, unless made of heat resisting alloys. Unless very carefully made, nickel alloys are said to be treacherous. Chain links made of nickel alloys, in a length of four inches, are known to have warped one-half inch. For certain purposes, chains can be run in guides below the hearth, while attachments to the chain links reach up into the furnace. In that case, the chain can be made of steel or malleable iron, but the attachments must be made of a heat resisting alloy. Chains carry vast quantities of heat into the open and depress the thermal efficiency of the furnace. This feature becomes serious if light material is conveyed through the furnace, and is most serious if electrical heat is used.

Chains of iron-chromium alloys do well in furnaces carrying a temperature of 1200 degrees Fahr. (650 degrees Cent.). If the temperature reaches 1400 degrees Fahr. (760 degrees Cent.), troubles are likely to arise, unless design, material, workmanship, and operation are excellent. If the temperature exceeds 1600 degrees Fahr. (870 degrees Cent.) chains should not be thought of.

For special purposes we use roller conveyors; for instance,

in the annealing of cast iron pipes, and in the annealing, heat treating and normalizing of sheets we use a series of rollers. The rollers are all turning in the same direction and the sheets are carried on top of them. Originally, the driving mechanism was made cheaply and consisted of chains running over sprockets. The motion was jerky. Every time a chain link slipped on a sprocket, a mark was made on the sheet. The finishing department, in such a case, had to do repeated cold rolling to cover up that mark. The rollers are now being driven either by worm gears or by machined bevel gears, for the purpose of avoiding the marking of the sheets. Furthermore, an absolutely non-scaling and reducing atmosphere must exist in the furnace or else the rollers will oxidize and scratch the sheets.

The Rocker Bar Furnace

The rocker bar furnace is another type which has been popular with inventors. Like the chain conveyor, it is good up to 1400 degrees Fahr. (760 degrees Cent.). I may repeat that in the lower temperature range of heat treating (below 1450 degrees Fahr.) many designs are practical which become utterly impracticable and impossible at higher temperatures. The rocker bar is a beam which extends through the whole length of the furnace and at times disappears under the hearth. It picks the materials to be heated off the hearth, carries it forward, and lays it down again. The rocker bar can make a circular motion, it can describe an ellipse or it can follow a rectangular path. All of these motions have been in use for many years, but, strange to say, only a few months ago a well-known firm in Philadelphia applied for a patent on the rectangular motion for a rocker bar and advertised the fact. Difficulties with the rocker bar are caused principally by warping of the beam. If the beam warps, then it refuses to move because it jams and binds in the grooves in the hearth. For that reason, and on account of trouble with scale in the beam groove, the rocker bar furnace is not as much used as the pusher type. In a comparison, we can say that one disadvantage of the pusher type is that practically all of the heat in the trays is lost. By the time the tray is picked off and rolled back and waits at the other end, it is so cold that most of the heat is gone. But we have the same disadvantage with most chain conveyors. In a certain sheet normalizing furnace it took three times as much fuel to heat

the chain as to heat the sheets. We can readily see where the thermal efficiency will be if we lose all that heat in a heavy chain. In that respect, the electrically heated furnace is at a disadvantage on account of the high cost of energy.

Drum Type Conveyor

The drum type conveyor, which consists of a revolving drum with an internal screw thread, is in great favor for heating small articles, such as balls and small rollers and any material of like dimensions, that is to say, not bar-shaped. The charge in the drum can be heated directly by hot gases which pass through the drum, or it can be heated from the outside, in which case the furnace acts as a muffle furnace. The material to be heated is carried between the helical ribs, comes in at one end and passes out the other end. Inclined drums without ribs can also be used for conveying. The transporting action exerted by them may be described as follows: As the drum revolves the material is carried up on an arc by friction, but, of course, it will not stay up, and slides back in a vertical plane. As it slides back it finds itself a little farther down. It is carried up again at right angles to the cylinder axis and slides back vertically. It moves along the drum in a zig-zag fashion. The same action occurs in a cement kiln. The smooth drum would never do for shapes that roll well, such as steel balls, and that is the reason why ribs had to be put in. The drum conveyor is quite automatic. At the charging end it is equipped with a big drum reservoir so arranged that it can be filled almost completely. But that reservoir admits only a few balls at a time into the main drum. The heated material is automatically dumped from the furnace into a quenching bath. The attendant dumps a charge of balls, rivets, or whatever it may be, into the reservoir drum. When they have passed through the furnace and have been quenched, they are removed automatically from the quenching bath with a minimum amount of labor. That type of furnace has paid its inventor well; it is one of the few exceptions.

Rotating Hearth Type

It is called doughnut type by some people. It has a ring-shaped hearth, or table. The material to be heated is laid on the hearth and is heated while it travels around the circular furnace. It is pulled out after having made almost a revolution. The ad-

vantage of this type of furnace is that most anything can be put on the hearth—a collar button as well as a railway coupler—any shape of material. The hearth carries everything around, heats it up, and brings it back. The disadvantage is that charging and discharging must be done by manual labor. And it is hard labor at that, because the material which has to be pulled out is hot. We ask, "Why not put an inclined scraper near the discharge door and scrape the heated material off the hearth and out through the door?" That scheme has been tried; again it works fairly well up to 1400 degrees Fahr., but above that it does not work well. If we can make the hearth a practically flat, seamless sheet of heat-resisting alloy that will not buckle, then that scraper arrangement can be made to work without catching. A disadvantage of the rotating hearth is that it does not fit nicely into a straight line of operations. It causes some waste space.

So much for methods of conveying the material through a furnace.

Method of Heat Application

A rather special method of heat application is partial heating, for instance, the heating of one end of a rod for bolt heading or similar work. That method does not occur often in heat treating except in tool hardening, in which case we heat only that end of the tool which is to be hardened, while the rest of the bar remains comparatively cold. That method requires a special type of furnace which is adapted to receive the end of the bar only, while the rest of it must be out in the open. But most heat treating is done in a manner in which the whole material is to be brought up to the heat, and then we meet the question: "How fast can we heat and how shall we apply the heat?"

All high carbon steels and many alloy steels must be handled with a great deal of care until the steel has passed through the range of blue-brittleness. If we take high carbon steel or some alloy steels and pull them in a testing machine while cold, they are ductile and "neck," as the technical term expresses it. If we increase the temperature to 500 or 600 degrees Fahr. and pull a test bar at that temperature, these same steels will not neck but will break off short. At that temperature the steel blues, and, therefore, we call this action the blue brittleness of steel. When we bring steel up through that range we must handle it carefully.

After we have it safely up to 700 degrees Fahr. we cannot injure it any more by fast heating except by burning, but below that temperature it is easily injured and will readily crack. Therefore, we must avoid expansion strains in the steel due to excessive temperature differences when the steel is being heated. After it is red to the core, we cannot hurt it any more. That fact is of the greatest importance in the application of heat in furnaces.

We cannot do good heat treating with a bright oil flame or a bright resistor right next to a piece of steel, because in such a case the outside of the steel will be heated quickly while the inside is still cold, and somewhere within that piece of steel there will be the combination of quick temperature drop with the critical range of the blue brittleness. When that steel is cooled again it is full of hidden internal cracks which await their chance to come out into the open. The world is full of steel that has been injured by fast heating. In this respect, a properly proportioned electrical furnace has the advantage that it heats up slowly. We buy electricity in a peculiar way. If we buy the same amount of energy all day long we get a certain low rate for it, but if we buy 100 kilowatts right along and just for a few minutes use 200 kilowatts and then drop down again, the utility company charges us a great deal more per kilowatt hour than if we had avoided the peak load. Heating up an electrically heated furnace from a cold start takes quite long because we do not want to put a large amount of energy into it at any time lest it bring up the demand rate. That may be a blessing in disguise because it keeps us from over-heating the steel. With oil, a furnace can be heated much more quickly, but the quality of the steel may suffer. In any event, we must avoid quick heating at one place while the steel stays cool elsewhere.

Permit me to dwell a little longer on the subjects of too rapid heating and of non-uniform heating. Rapid heating causes non-uniform expansion; if the material being heated is of limited ductility (cast iron, for instance, or steel in the blue brittle range) a great difference of expansion of immediately adjacent layers causes rupture. It is advisable to limit the rate at which heat can be supplied because of the danger of rapid heating. There are heaters who are dissatisfied with slow heating and who prefer a furnace which can be heated quickly. A furnace of that type may be safe if entrusted to a careful man, but why run any risks?

So much for rapid heating. The other requirement of furnace design, namely, uniformity of heating, is just as important. Even if the rate of heating be slow, there can still be cold spots, due, for instance, to heat abstraction by a cold hearth. If such lack of uniformity exists, uniform heat treating and uniformly perfect material are impossible. The requirement of uniform heating has been of great influence upon furnace design. Let us consider an oil-fired furnace as an example. The temperature of an oil flame exceeds 3000 degrees Fahr. If an oil flame is allowed to burn in the heating chamber in close proximity to the stock to be heated, over-heating of some parts and non-uniform heating of the charge are certain. That is the reason why, in oil firing of heat treating furnaces, we must burn the oil in a separate combustion chamber, with the intention of sending a uniformly diffused heat into the heating chamber. A commonly used (but by no means the best) type of oil-fired furnace is the so-called overfired type, in which the oil is burned, or at least partially burned, above a perforated arch and the products of combustion sink down through the perforations into the heating chamber. In this type of furnace the temperature can be distributed uniformly in a horizontal plane, but often temperature differences are found to exist up and down. The hearth is liable to be cold. The last named trouble is avoided in the so-called under-fired furnace, in which the oil burns in a combustion chamber under the hearth. The products of combustion rise through side flues and circulate above the hearth. If the rate of heating (expressed, for instance, in pounds of steel heated per square foot of hearth and per hour) is kept low enough, say around 30 pounds, uniform heating can be obtained with this type of furnace. However, the thermal efficiency is rather low in that case, because a great deal of heat is lost from the combustion chamber by radiation and convection. It will not do to make the combustion chamber small, neither can it be protected by insulation, because of injury to the refractory material.

An effective method of reducing the temperature of an oil flame or a gas flame, consists in recirculation of the furnace gases. If the jet of atomized oil and air (or steam) is so directed that it can entrain a large volume of furnace atmosphere, the flame gases are so much diluted by furnace atmosphere that no overheating can occur. If, moreover, the circulating and well diluted

products of combustion are directed to wend their way between and under the pieces which make up the charge, a most excellent uniformity of heating can be obtained. The principles of recirculation and of underfiring have been combined, and with good results.

With gas fuel, the danger of overheating or of non-uniform heating is not as great as it is with oil fuel. It is true that the temperature of the gas flame is also high, but a gas flame has the advantage (in this case) that it is non-luminous. From experience we know that non-luminous gases radiate heat only about ¼ or ⅕ as fast as a luminous flame, which in reality is a stream of hot gas with glowing carbon particles. On account of this difference the danger of overheating is not nearly as great with gas as it is with an oil flame. For that reason, gas is usually burned directly in the heating chamber, whereas oil is burned in a separate combustion chamber.

It might appear that we could get rid of these heating troubles by the use of electric heat. However, electric heat in itself is no guarantee for uniform heating. Improper arrangement of the resistors, and improper packing of the charge result in great temperature differences in the charge. It must be remembered that there is little circulation of gases in an electrically heated furnace.

One more method of heat application should be mentioned, and that is the method of using the material to be heated as a resistor. If we pass an electric current through a bar with uniform cross-section, it will be heated almost uniformly; the center is slightly hotter than the outside. This method, which is now quite common for heating rivets has also been used quite successfully for annealing brass tubes. Its application in the field of steel treating appears to be sharply limited, because it cannot be used on bars of varying cross-section, unless we are satisfied to have a lower temperature in the thick sections than in the thin sections.

In conclusion the author wishes to repeat that a paper of this sort can, at best, give only a bird's-eye view or, to use another simile, hit the high spots of such a broad subject.

EQUIPMENT FOR HEAT TREATING MACHINE TOOL PARTS

By D. M. Gurney

Abstract

This paper describes the layout and heat treating equipment which is being used by one of the largest producers of semi-automatic lathe tools. While this heat treating plant was designed a number of years ago, the details of layout, equipment and type of materials being treated were so carefully considered that little if any change in the layout would be made in the installation of a new plant today.

FROM a casual observation of machine tools in general, it would seem that a considerable amount of heat treating is necessary in their production. Upon careful analysis of the situation it will be seen that while there are many intricate parts which do require heat treatment, the main structural parts consist of castings which are not heat treated. With this point in mind, it will be appreciated that an exceedingly large heat treating department is not necessary in the production of machine tools, although a well organized and laid out plant capable of taking care of an even flow of material is essential. This has been accomplished to a nicety in the plant of The Warner and Swasey Company of Cleveland.

There are many types and sizes of cutting tools, jigs, fixtures and intricate parts combined in finished machine tools as manufactured today. Many of these large tools are built upon standard lines, but are supplied with special equipment to take care of the needs of the individual purchaser. While it is nearly impossible to tabulate all of the parts which are heat treated in this plant, the following list will give a fair idea of the materials which are daily hardened in this small but amply large heat treating department.

Materials Heat Treated

Bushings of all types	Centers
Bolts of all types	Spring Collets
Cams	Gears of all types
Collars	High Speed Cutters

The author, D. M. Gurney, member A. S. S. T., is metallurgist, The Warner and Swasey Co., Cleveland.

Pilot Bars	Carburizing and oil quenching Alloy Steels
Tool Holders	Washers
Screws of all types	Nuts
Carbon Steel Cutters	Boring Bars
Pinions	Studs of all types
Shafts	Springs
Rods	Tool Posts
Rolls	Wrenches
Pins	

Layout of Heat Treating Shop

The heat treating department is housed in a separate brick hip-roof mill building which is adjacent to the general assembly floor. The layout of this heat treating shop is shown in the floor plan, Fig. 1. This unit is 100 feet long and 45 feet wide. Three-quarters of this space is devoted to heat treating equipment, while the balance is devoted to a small forge shop.

Furnace Equipment

The furnace equipment consists of the following:

	Floor Space	Oven Size
2—Carburizing furnaces	124x70 inches	72x42x22 inches
4—Carburizing and hardening furnaces	98x55 inches	48x27x19 inches
4—Hardening furnaces	76x53 inches	36x24x12 inches
1—High speed steel furnace with preheater	66x30 inches	14x 8x 4 inches
1—Double lead pot		
1—Single lead pot		
1—Nitrate of soda tempering bath furnace		
1—Cyanide hardening and heating furnaces		
1—Hot slushing solution bath		
1—Hot soda bath		
1—Electric tempering furnace		

Each furnace is equipped with both oil and gas burners. Due to the constantly increasing cost of natural and city gas, these furnaces are heated almost entirely with fuel oil, gas being used only

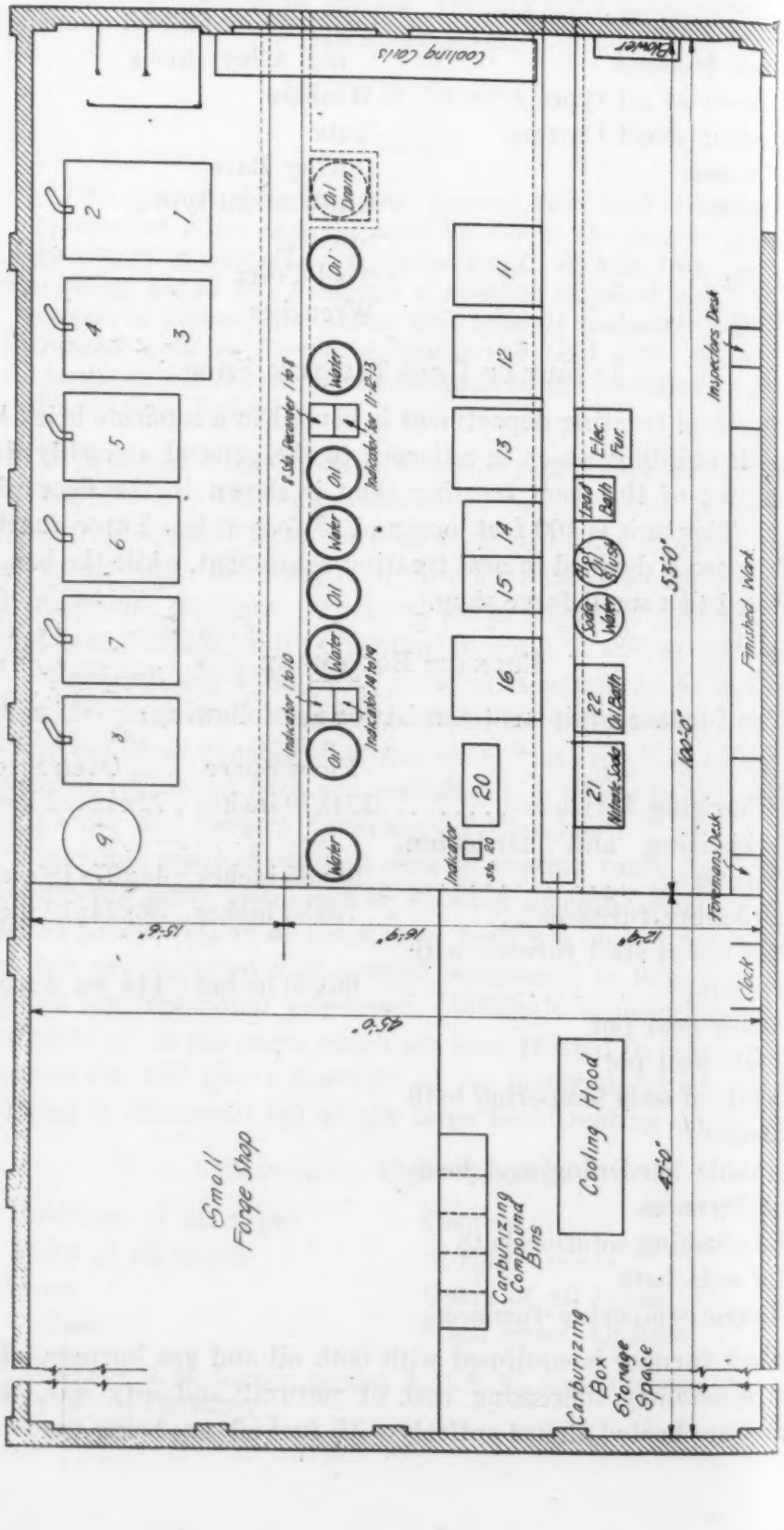


Fig. 1—Floor Plan of Heat Treating Department.

in the case of emergencies. In case of trouble with the oil supply, operations may be continued by opening a large valve in the gas main, which is located in the heat treating room. The two large carburizing furnaces (Nos. 1-2 and 3-4) are each equipped with 12 gas burners (6 on each side) and 4 oil burners (2 on each end).

Fig. 2—This Photograph Shows Six Carburizing and Hardening Furnaces as well as the Quenching Tanks, Hoists and Indicating and Recording Pyrometer System. It will be Observed that the Operator is Charging a Carburizing Box in a Furnace from the Portable Steel Table. The Hoods and Ventilating System are Clearly Shown.

These furnaces are of the under-fired type. The 4 smaller carburizing furnaces (Nos. 5, 6, 7 and 8) are each equipped with 8 gas burners (4 on each side) and 2 oil burners (1 on each side). All of the other furnaces in the heat treating room are equipped in the same manner with gas and oil burners, with twice as many gas burners as there are oil burners.

Each furnace is equipped with a large hood which carries off smoke, heat, excess gas and fumes which otherwise would be diffused into the hardening room. Each of these hoods is supplied with a large ventilator pipe which extends to a monitor mounted on the roof. (Figs. 2, 3, and 4). In addition there is one large hood over

Fig. 1—Floor Plan of Heat Treating Department.

the carburizing-box cooling-table. Eleven of these hoods, ventilator pipes and monitors, comprise the ventilating equipment of this hardening room.

All of the furnaces are equipped with one or more thermocouples. The number on each furnace (Fig. 1) designates not only

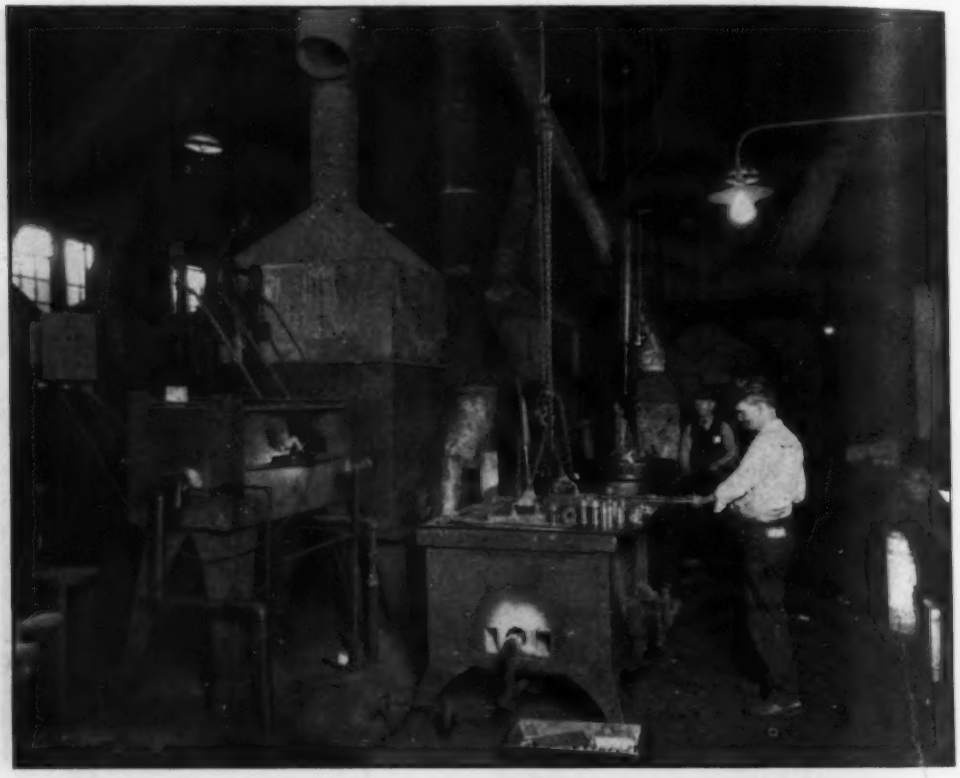


Fig 3—Photograph Showing Tempering Furnaces and High Speed Steel Hardening Furnace.

the serial number of the furnace, but also the number of the thermocouples in the furnace. For example, furnace No. 3-4 contains thermocouple No. 3 and thermocouple No. 4, while furnace No. 5 contains thermocouple No. 5. The number of each thermocouple corresponds to the respective station-number on the 8-station recorder or multiple-station indicator. The temperature of thermocouples 1 to 8 are recorded on the 8-station recorder, while temperature of the other thermocouples is indicated on the multiple-point indicator. The recorder and indicator are conveniently located in the center aisle so that they may be readily observed by operators working on either line of furnaces. The instruments are mounted on springs and set on concrete piers which extend 3 feet underground.

This method eliminates vibration from the forge shop and railroad.

Carburizing

The procedure followed out in this plant in the carburizing of parts has been well planned. The empty carburizing boxes are

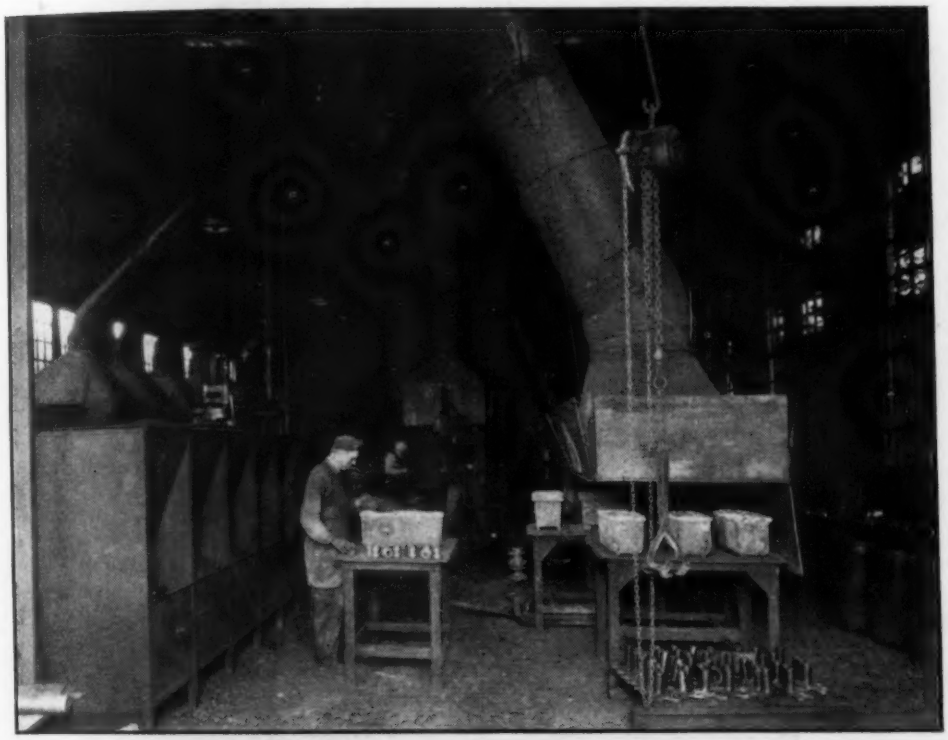


Fig. 4—Photograph Showing Operator Packing a Carburizing Box. It will be Observed that the Box is on one of the Portable Steel Tables. The Cooling Hood may be Seen on the Right and the Carburizing Compound Bins on the Left.

placed on a portable steel table which is so constructed that an elevating truck may be placed under it so that it may be transported from place to place. When packing the carburizing boxes with parts to be carburized, they are placed on a steel table in front of the carburizing-compound bins. (Fig. 4). In packing the boxes the usual care is exercised to prevent the pieces from touching each other or from touching the sides of the carburizing box.

Two types of boxes are used, rectangular and circular, the circular box having a chimney through the center to facilitate heating. It has been the practice in this plant to standardize on the width and height of the boxes and vary the length according to the materials being carburized. The height and width has been established according to the dimensions of the furnaces, allowing suffi-

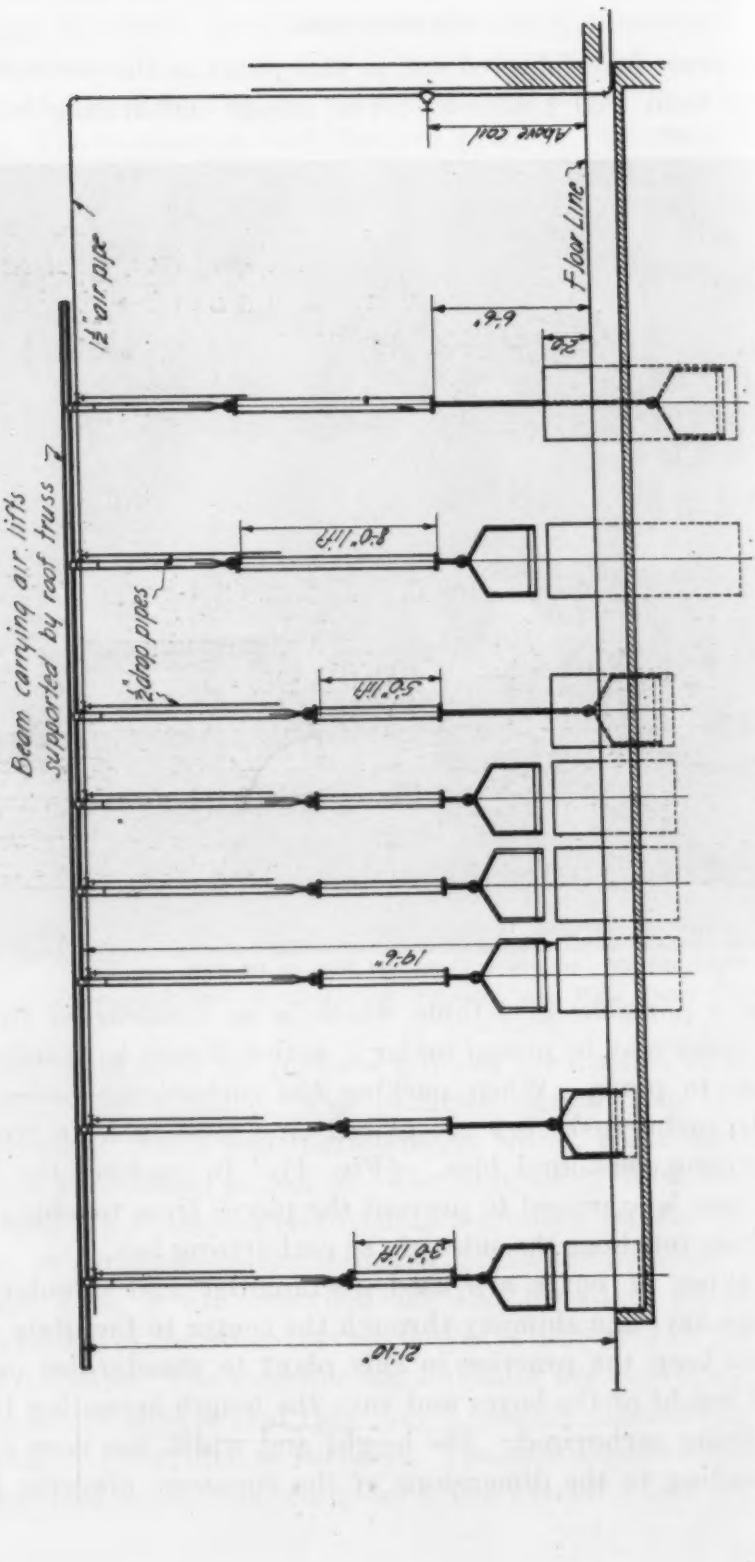


Fig. 5—Sketch Showing Elevation of Quenching Tank System of Air Hoists and Baskets.

cient space between the boxes to provide proper venting and heating. For the most part, this plant has standardized on cast steel boxes.

The storage bin for the carburizing compound has been divided into five compartments. Each compartment contains carburizing

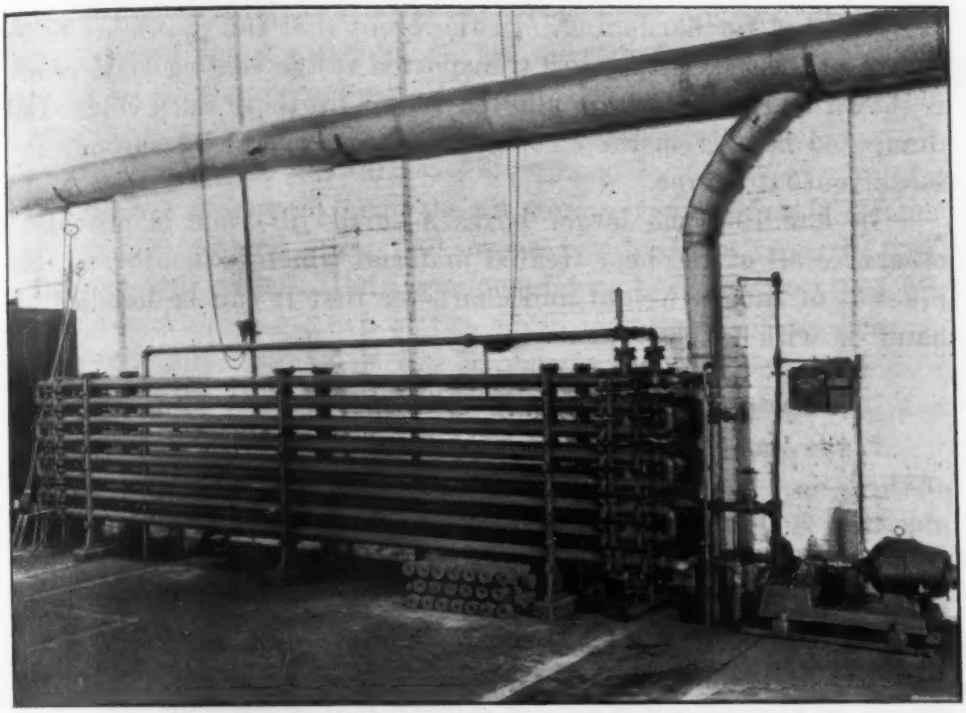


Fig. 6—Photograph of Cooling Coils and Circulating Pump Used in Maintaining Quenching Oil at Uniform Temperature.

material which has been used from one to four times. Bin No. 1 contains new material; bin No. 2 contains material which has been used only once; bin No. 3 contains material which has been heated two times; bin No. 4 contains material which has been heated three times; and bin No. 5 contains material which has been heated four times. Carburizing material which has been heated more than four times is discarded. Certain combinations of these different materials are used according to the requirements of the parts which are to be carburized.

After the boxes are properly packed and the covers luted on, the entire table is then transported to the furnace in which they are to be heated. The elevating truck is released and the height of the table then corresponds to the height of the furnace hearth (Fig. 2). The boxes are then charged into the furnace by means of a charg-

ing truck. Fig. 2 shows an operator charging a box into a furnace. The practice in this plant is to carburize at 1650 degrees Fahr. for the time which is necessary to obtain the desired depth of case.

After the pieces have been carburized for the required length of time, they are taken out of the furnace and are either quenched directly or allowed to cool to room temperature, after which they are reheated for hardening. In the event that the pieces are to be cooled in the boxes, they are transported to the cooling hood which is shown in Fig. 4 and are allowed to remain there until cold. The dissipated heat from these cooling boxes is carried off through the large ventilator pipe.

In handling the larger boxes a small jib-crane is provided; otherwise all of the heat treated material which is handled in this plant is of such a weight and character that it can be handled by hand or with trucks.

Quenching Equipment

Eight quenching tanks are installed between the two main rows of furnaces. They are alternately arranged, oil and water, and are placed in such a manner that they serve both rows of furnaces. All of these quenching tanks are set down into the floor with approximately two feet extending above the floor level. See Fig. 5. The two tanks opposite the large carburizing furnaces are 8 feet deep. The next four tanks are 5 feet deep and the last two are 3 feet deep. The quenching system being of the circulating type, the tanks are provided with over-flow pipes for conducting the quenching media back into the cooling coils. The tanks are filled to within 12 inches of the top.

Over each tank is mounted an air hoist having a piston length equivalent to the depth of the tank. A wire basket is fastened to the end of this piston into which the heated pieces to be hardened are placed. When quenching heated pieces, this air hoist is set into operation and the basket is caused to move up and down in the quenching medium. These may be clearly seen in Fig. 2. A reversing mechanism has been provided on each of these hoists so that they may be automatically reversed, until such time as the operator shuts off the air. This mechanism provides an excellent method of agitating the quenching medium, although the oil and water is in constant circulation by means of a circulating pump which circulates the oil through a cooling coil. This cooling coil was an adoption from a

refrigerating machine used in the production of manufactured ice. It has since been commercially marketed for use for a cooling system in heat treating plants. This cooling coil is shown in Fig. 6.

The quenching oil (27 barrels) is stored in a large tank placed underground and in line with the quenching tanks. The overflow from the quenching tanks returns to the storage tank, and in turn is circulated through the water-cooled cooling coils. City water flows through inner pipes which are surrounded by larger pipes through which the quenching oil flows. The temperature of the oil is regulated by the rapidity of its flow through the system.

The fuel oil for the furnaces is pumped by means of a rotary pump placed at a point near the oil storage tank which is located adjacent to a railroad siding and several hundred feet from the heat treatment department. An ingenious device has been provided for the automatic closing down of the pump in the case of accident or unexpected interruption of the combustion air. This device is a magnetically operated one which has proven very efficient and was invented by the electrical engineer of this company.

The combustion air is supplied by a large rotary blower supplying air at 6 to 8 ounces of pressure. One of these blowers is installed in the heat treating room and a second auxiliary blower is installed in the power plant which is located close by.

One of the unique features of this plant is that all of the wiring, pipe lines and drains, have been placed in conduits under the floor. The conduits are accessible, being simply covered by corrugated steel flooring.

Tempering

The tempering of hardened parts is accomplished by several methods. This plant is provided with oil tempering baths, salt tempering baths, lead baths and electric resistance oven furnaces as shown in Fig. 3.

A number of the parts, after tempering, are placed in a bath of grease. This bath is maintained at about 250 degrees Fahr; and the parts are immersed for a few minutes. When they are removed, a thin film of grease solidifies which protects the steel from corrosion.

High Speed Steel Hardening

The hardening of high speed steel tools is accomplished by

means of the well known type of preheating oil-fired muffle furnace. The quenching of tools made of high speed steel is usually done in a small tank of oil which is arranged in a similar manner to the air hoist quenching tanks previously described, but which is operated by hand.

Although this plant was designed a number of years ago, it is doubtful whether many improvements could be made in the layout or facilities for heat treating parts for the master tools of industry.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Criticism in This Column—Members Submitting Discussions Are Requested to give Their Names and Addresses

ON HIGH POWER PHOTOMICROGRAPHY

By S. L. Hoyt

THE subject of high power photomicrography has been prominently placed before this Society by the recent papers of F. F. Lucas[1]. The photomicrographs reproduced in TRANSACTIONS are sure to excite the keen interest and admiration of those engaged in metallic microscopy. The extent to which the magnification has been pushed and the general quality of the photographic technique seem to leave little to be desired, unless it be the use of ultra-violet light. These are matters which call for no further mention except to say that the work gives an excellent opportunity to judge the value of ultra-high magnifications in scientific work.

The scientific side of the work, however, deserves further consideration, and it is about this element of the work that the present discussion will be centered.

The general question to which the present paper relates is that raised by Mr. Lucas in stating his belief that photography at magnifications in excess of 1500 x is of value and that "high power metallography brings a new tool to the scientific worker." Such a discussion would naturally divide itself into (1) the utility of high magnifications in general, and (2) the nature and value of the evidence obtained in the present case.

The general position taken in this discussion is that the usefulness of the microscope in high power work is to be increased, if at all, by increasing the resolving power of the optical system and not, as recommended by Mr. Lucas, by enlargement of the image of the objective. Inasmuch as the papers referred to touch on the metallography of steel, it too will be dealt with.

It is well known that the apochromatic objectives used by Mr. Lucas are capable of resolving remarkably fine details. It is just in this respect that they are superior to the older, or achromatic objectives. In magnifying power, per se, they are neither better, nor worse. So important is this distinction between magnifying power and resolving power, and so elusive, that it may be worth while to consider the apochromatic objectives from this point of view.

The introduction of these objectives in 1886 greatly increased the range

[1] "High Power Photomicrography of Metallurgical Specimens," by F. F. Lucas, TRANSACTIONS of American Society for Steel Treating, November, 1923, Vol. 4, page 611.

The author of this discussion, Dr. S. L. Hoyt, member A. S. S. T., research laboratory, General Electric Co., Schenectady, N. Y.

of microscopic vision and experimental data of great importance have been obtained which otherwise would probably never have been procured. Great, then, is the debt which science owes to Prof. Ernst Abbe and his co-workers of the staff of Carl Zeiss. Indeed, we may regard the development of these lenses as one of the outstanding achievements of physics when we consider the theoretical analysis of image formation, which established the basis of their design; the experimental work by means of which the theories developed were given adequate verification and the properties of the lenses were definitely ascertained; and the commercial marketing of the lenses which finally placed them at the disposal of scientific workers in all parts of the world.

So thoroughly was this work done and so firm are the foundations on which both the theoretical and the experimental work rest, that nothing short of monumental proof would cast serious doubt on the validity of our present conceptions of the properties and limitations of these lenses.

A more concrete idea of the value of the apochromatic lens comes from a consideration of "resolving power" and "magnification." In this brief discussion we shall leave out of consideration "secondary visibility" by means of which the presence of dust particles in air or water may be observed when they are properly illuminated, but which tells nothing of the size, shape, and structure of the particles.

The compound microscope consists of two parts, the objective and the ocular, each of which has a very definite function to perform. The *primary* function of the objective is to form or reproduce an image of the subject. This image is known as a "real" image, and is similar to the one produced in an ordinary camera on the film or plate. This image is larger in physical dimensions than the subject, and so represents a "magnification," but in microscopic practice it is so small in actual size that the unaided eye would be incapable of perceiving its details. The necessity of making these details visible introduces the human element as an important, though only too frequently neglected, factor in microscopic procedure.

The normal human eye can see a disc the size of our quarter dollar at about 250 feet. At this distance a quarter subtends an arc of about 1 minute which is about the lower limit of visibility. If we are to avoid eye strain, objects should appear about 2 minutes in size. The image produced by our microscope objectives contains details which at normal reading distance come well below 2 minutes or even 1 minute in size. Quite naturally it becomes necessary to enlarge the image in some way, by means of an ocular, by projection on a photographic plate or on a screen.

The function, then, of the objective is image formation and of the ocular is image observation. The highest powered objectives produce an image which is about 100 times as large as the object. This image is commonly magnified about 10 times to give an overall magnification of about 1000. Mr. Lucas magnifies the image about 50 times which makes one ask if the 5000 x tells us anything which is missed at 1000 x. The answer is inseparably related to the "resolving power" of the optical system.

In normal vision, that is, with the unaided eye, we have no exact counterpart of "resolving power." The factors governing vision are simply size and illumination, and thus it comes about that the production of an image of an object by means of an objective introduces a new factor, one with which we do not commonly have to deal. Let us suppose that the object under examination is composed of particles ranging from extremely small or submicroscopic upwards. These particles, we may assume, are of the size of a wave length of light. If, now, we have a loose cluster of these small particles in the field, the cluster will be reproduced as a whole in the image as one element, but the particles themselves will not be reproduced. The reason for this is that the particles lie so close together that the interference phenomena, which result from the action of the particles on the rays of light and produce the image, overlap each other. Commonly stated, the particles are not "resolved." No amount of subsequent magnification will separate the images of the particles for they will always overlap.

The fact is, structural details must be of at least a certain size, d, before they are reproduced, by a given light source, in the image. The limit of resolving power, d, can be expressed

$$d = \frac{\lambda}{n \sin u} = \frac{\lambda}{N.A.}, \qquad (1)$$

where λ is the wave length of the light used, n, is the refractive index of the medium between the object and objective (air or oil) and u is ½ of the angle of aperture. The quantity n sin u is known as the numerical aperture, N. A. A cluster of particles of size larger than d would be properly represented in the image as a cluster and not as a single particle.

This factor of resolving power sets a very definite limitation on the objective, or on the optical system. Below that, we can not go. Even so there are factors which may prevent the full utilization of the resolving power of the objective, for the image may be so full of aberration, chromatic and spherical, that its details will be poorly defined or blurred. In practice this is just as serious a fault as lack of resolving power. It is to the credit of the apochromatic lenses designed by Abbe that these aberrations have been so well corrected that we may make full use of their great resolving power. This statement is made simply to bring out the fact that good correction itself neither adds to nor corrects the resolving power, but is vitally necessary to its full utilization.

A reference to the size of the image actually reproduced and of the component parts of the image makes it at once evident that the human eye, with the limitations already mentioned, cannot possibly see the details which are there. The eye can see about 200 lines per inch. Suppose we are examining a structure with 150,000 lines per inch of the kind used by Mr. Lucas. In the image from the objective, this would still amount to 1500 lines per inch, and we would have to magnify it some 7 or 8 times in the eyepiece. This shows the necessity of magnifying the image. It is at once evident that this

enlargement is simply to permit visual examination without undue eyestrain, and that it cannot possibly add anything to the image which is not already there.

Abbe has pointed out that it is useful to magnify the image to such an extent that the smallest components of the image, or the smallest particles resolved in the image, appear to be about 2 minutes to the eye. This permits easy examination of the image. A magnification which makes the smallest elements appear larger than 4 minutes is unnecessary, and in fact magnification above this amount simply spreads them out over a larger area, and makes them appear dimmer and poorly defined. This higher magnification is useful for certain purposes, such as for projection on a screen at a distance to allow a group of people to view the image, but no further details are brought out. This type of image is said to be "empty."

Reading from the book of Scheffer of the Zeiss staff we see that Abbe has determined the range of useful magnification for white light (wave length = 0.55 μ) and the numerical aperture used by Mr. Lucas of 1.40, to be from 741 x to 1481 x. In other words, the magnification should be at least 741 x to make visible all the little details which the system is capable of resolving, but magnifications of over 1481 x detract from rather than add to the quality of the image. The use of blue light of wave length $\lambda = 0.4\ \mu$, would increase the range of useful magnification to 1050 — 2100 x. A finer structure than the one assumed would not be resolved regardless of the magnification, while a coarser structure could be profitably observed with a system of lower numerical aperture.

To sum up, we have seen how highly improbable it is, with a numerical aperture of 1.4 and blue light with vertical illumination, that a magnification greatly in excess of 1000 x would be of advantage. The work on which these conclusions are based sets a standard for skill and thoroughness, and it seems to be entirely within reason to require of anyone who claims exceptional value in magnifications higher than those recommended by Abbe, that he show wherein the superiority lies and establish a sound theoretical basis for his conclusions.

We are now in a position to examine somewhat more critically the evidence used by Mr. Lucas in arriving at his conclusions, and the methods used to secure the evidence. As a general proposition of scientific procedure if one is to study the properties and limitations of a lens, he should use a subject for examination whose structure is known and defined. Thus Abbe used ruled gratings of various kinds as well as such natural preparations as diatoms. In this way he was able to establish the laws relating the aperture and wave length to the resolving power. Those who are especially interested are advised to look up this work if they wish to see how definitely the relationship is known and on what a sound basis it rests.

To come more directly to the subject of the papers, the structures of the preparations used are too poorly defined to be of any scientific value in answering a question of this kind. A structure which is assumed to be discovered for the first time can hardly be used to determine the limitations of

the optical system used in discovering it, or, in other words, the value of ultra high-power microscopy. Certain structural features are cited of the magnitude of 0.000006 inch, but this is at the very limit of the theoretical resolving power of the system. In other words, the distance across the structure under examination is practically the same as the wave length of the light used. The assumptions that these images are exact replica, on a large scale, of the structure of the object, must rest on a very insecure foundation. It is well known, for example, that these conditions can lead to the elimination of certain of the diffraction maxima which make the image and thus give an image which bears no resemblance to the object. The logical conclusions at present would be that the ultra-high magnifications used have not brought out any details over and above those which a magnification of around 1000 x would show, and that details which, on account of their fineness, would require a magnification of say 5000 x to render them visible, would be quite too fine to be resolved by the system used. Working with unknown preparations, indefinite answers must be the result.

Aside from these theoretical considerations we are, happily, in a position to judge from the results proper of the utility of ultra-high power photography. The field covered is the microstructure of high carbon steel when quenched from at or near the freezing point. This field has also been covered by Hanemann, Maurer and others, and a fairly careful reading of the papers has failed to reveal, except for some minor points which are still controversial, that the older ideas require revision.

By way of illustrating the point the present writer ventures to point out a few matters which Mr. Lucas apparently feels are new and due to the superiority of ultra-high magnifications.

We may read, for example, in reference to Fig. 5 of the *second paper*[2] that "if objectives of high primary magnification and high numerical aperture were not available it is likely the details of this structure would have remained a mystery." The structure in question has been shown by Hanemann for one, to be the white iron eutectic, Ledeburite, and its formation under the conditions of this experiment is well known. Again, regarding the allotropic nature of iron, we find simply a confirmation of our older ideas when we read that his work "points very strongly to the existence of iron in two allotropic forms." There is this difference, however. The older work has convinced us, beyond all doubt, that iron is allotropic and has taught us considerable concerning the allotropes.

As to the supposed relations between polyhedral grains and dendrites, the statements made are so at variance with the customary teachings of this subject that they can hardly be accepted as evidence of the utility of ultra-high magnifications. Again, the X-ray method of crystal analysis has taught us that the atomic arrangement of austenite is face-centered cubic, and represents a considerable advance over the conclusions of the second paper on the point. That martensite is granular or lamellar cannot be said to be proved by the paper due principally to the fact that the basis of such proof is entirely lack-

[2] "The Microstructure of Austenite and Martensite," by F. F. Lucas, TRANSACTIONS of American Society for Steel Treating, December, 1924, Vol. 6, page 669.

ing. The presence of ferrite as tiny cubes in austenite and martensite, as inferred from cubical etching pits, is also an assumption of dubious nature. Ordinarily one assumes from cubical etching pits simply that the atomic arrangement is cubical, with no assumptions of the presence of inclusions. Furthermore, we know that lamellar pearlite, said to be formed from the cubes of ferrite, does not come from austenite and martensite (by tempering). The granular pearlite, which does form, contains ferrite in acicular grains (Hanemann).

The present discussion will probably suffice to indicate the very great, if not insurmountable, difficulties which lie in the way of any attempt to increase the amount which can be seen with a well corrected apochromatic objective and visible light for illumination, over and above that which is given by a magnification of 1000x, by the expedient of further extending the final magnification. Theory opposes it and practice does not support it. However, there is one method which may be used to improve our vision, a hint of which has already been given, and that is the use of ultra-violet light. According to formula (1) we see that the resolving power, given by d, can be extended if we can employ a shorter wave length. It is the writer's understanding that Mr. Lucas is engaged in work which carries out this line of thought, and it is not too much to say that all metallurgists will await his results with the keenest interest.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested To Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION NO. 160. Is there any salt or combination of salts, which will melt at or below 350 degrees Fahr.? Will this salt be stable?

QUESTION NO. 161. What becomes of the excess carbon above that which can be combined with other elements to form austenite? What would be the form designation of such carbon and what effect would it produce as regards the structure and physical properties of the metal, assuming that other alloying constituents were present in sufficient quantity to reduce the factor of brittleness to within the range of lower carbon steels?

ANSWERS TO QUESTIONS

QUESTION NO. 134. What are the usual feeds and speeds used in machining both carbon and alloy automotive steels, when using high speed steel cutting tools?

QUESTION NO. 137. What is the mechanism of the iodine etch for the deep etching of steel?

QUESTION NO. 138. Is the electrolytic pickling process being used to show up defects in steel bars? If so, how does it compare with the regular pickling processes?

QUESTION NO. 142. What is the consensus of opinion of the cause of blisters in low and high grade steels sheets?

QUESTION NO. 143. How can these blisters be eliminated?

QUESTION NO. 144. Why do many chromium-nickel steels show a laminated structure when viewed under the microscope?

QUESTION NO. 149. Do plates of basic open hearth steel ever have a higher base rate than acid open hearth steel?

QUESTION NO. 151. What effect does the temperature of an oil-quenching bath have upon the hardness of a piece of steel quenched into it from the proper hardening temperature?

QUESTION NO. 152. *Is manganese up to 1.50 per cent detrimental in a steel to be used for carburizing purposes? How does the high manganese content affect the final product?*

QUESTION NO. 147. *Is it desirable or necessary to periodically anneal the chains used on cranes? If so, why?*

ANSWER. Extract from the British publication *Engineering.*

"Quite a number of articles, such as chains and hooks, and high pressure gas cylinders, are required, both by official regulation and by established practice, to be annealed at more or less frequent intervals. There can be no manner of doubt as to the idea underlying this practice. Put in the most general way, it is simply that soft iron and steel are known to become hardened when overstrained, and, if this overstraining is carried sufficiently far, it is known to exhaust their ductility and to render them brittle. On the other hand, "annealing" is known to soften these metals, and thus, obviously, to undo the harmful embrittling effects of severe overstrain. Hence, the argument runs, since articles which are at times liable to break must on more frequent occasions be seriously overstrained, they are likely to become brittle by use, and can only be kept in a safe condition by frequent annealing. Even more frequently, we meet with the deep-rooted, but really quite unfounded, idea that vibration and fatigue cause iron and steel to become brittle by undergoing "crystallization," and that this defect also can be removed by annealing. The advances of metallurgical knowledge during the past twenty years have thrown entirely new light on these matters, and the time has surely come to look into this question and to decide afresh whether this annealing practice is satisfactory or desirable, and particularly whether official regulations demanding it are right and proper.

"The matter raises two distinct, but not entirely independent, questions. First, whether any kind of "annealing" process is either necessary or desirable, and, secondly, if it is, whether the annealing process as ordinarily employed in practice is satisfactory or adequate. In seeking an answer to the first question, we must consider separately the hardening of iron or mild steel by overstrain and the supposed "crystallization" from fatigue or vibration. The first is easily dealt with. Overstrain certainly hardens such materials and tends to render them brittle, but this tendency only becomes serious if the amount of actual plastic deformation becomes relatively large. A wrought iron or mild steel that did not show a 20 per cent elongation on test would hardly be regarded as suitable for use in a chain; yet a chain that exhibited anything like a 10 per cent actual elongation of the material, as distinct from mere lengthening of the chain as a whole, owing to the straightening of curved links, would be looked upon with more than suspicion in practice. It may therfore be safely concluded that any *considerable* amount of plastic deformation would not be tolerated in use, and that, therefore, any serious hardening, with its consequent brittleness, is not likely to occur—and cannot occur—without detection by any reasonable system of inspection in ordinary practice. For the purpose of removing hardness and brittleness due to over-train, therefore, annealing is not required. Turning now to the effects of

(Continued on Page 51 Adv. Sec.)

Reviews of Recent Patents

By
NELSON LITTELL, Patent Attorney
110 E. 42nd St., New York City
Member of A. S. S. T.

1,537,381, Cutting and Milling Tool and Method of Manufacturing the Same, Benno Strauss, of Essen, Germany, assignor to Fried. Krupp Aktiengesellschaft, of Essen-on-the Ruhr, Germany.

This patent describes the making of cutting or milling tools from an iron alloy not capable of hardening per se, that is, comprising 0.1 to 0.2 per cent carbon and 8 to 14 per cent of chromium, and then cementing or case hardening the cutting edge in the customary manner and finally subjecting the tool to the usual tempering process by heating and quenching. In this manner a tool can be produced in which the cemented cutting edge becomes glass-hard, whereas the adjoining layers of steel obtain a gradual degree of hardness and a great toughness, which permits the tool to withstand the shocks created by the working without snapping off.

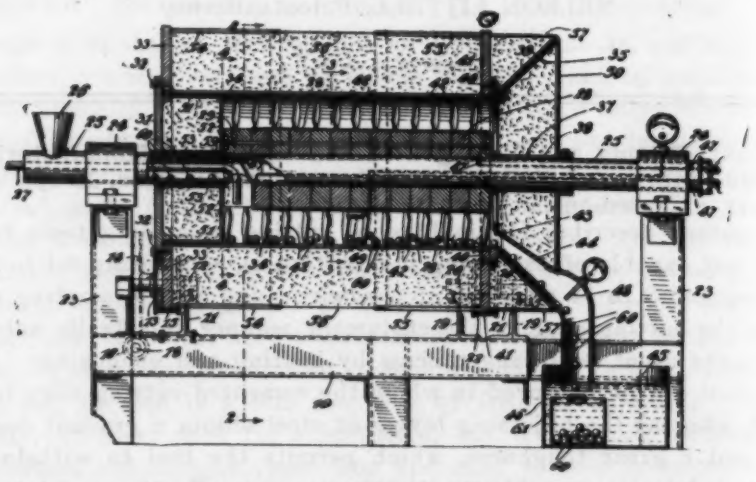
1,537,709, Process of Removing Non-Metallic Inclusions from Iron or Steel, Hugh C. Sicard, of New York City.

This patent relates to the scavenging or deoxidizing of molten steel, in which in addition to the aluminum which is ordinarily used as deoxidizer, titanic oxide is added to flux out the alumina which is often entrapped in the steel as a result of the deoxidizing by aluminum. The inventor has discovered that titanic oxide is a suitable fluxing agent for the alumina, and that when alumina and titanic oxide are heated together, a much more fusible compound is formed than the alumina itself. In practicing the invention, the titanic oxide is thrown into the ladle immediately after the furnace has been tapped, and when the ladle is about three-quarters full, the aluminum is added. The aluminum is immediately oxidized, and the alumina thus produced fluxes with the titanic oxide, and frees itself from the molten steel.

1,538,365, Electric Furnace, Edwin L. Willson, of Farmington, Connecticut.

This patent discloses an electric furnace for uniformly heating small articles such as bearing balls, chain links, or the like, for the purpose of hardening or imparting other desired properties to the same. The furnace comprises a circular drum 56, the walls of which are suitably packed or insulated by means of insulating materials packed in the chamber walls. The drum rests on suitable rollers carried in standards 11 and 19 and is rotatable on the rollers around the stationary hub 25 and stationary heating element 28. The heating element 28 is wound with suitable conducting wires 47 which enter the furnace through the shaft 25 and radiate heat to the interior of the drum 56. The interior opening of the drum 56 is provided with spiral ribbon-like conveyor members 42 which gradually convey the articles which are in-

serted through the hopper 26 and hub 25 from one end of the furnace to the other during the rotation of the drum 56. Suitable carburizing or reducing gases may be introduced into the furnace through the pipe 27. The articles under treatment are discharged through the opening 44 into a suitable vessel



45 containing an oil or water quenching medium. The operation of the furnace is continuous, and the articles passing through are heated to a uniform degree and may be kept in the heated furnace various times, depending upon the slope of the spiral 42 and the rate of rotation of the furnace.

1,538,411, Process of Treating Steel, Hiroshi Shiokawa, of Kobe, Japan.

This patent relates to a process of treating or annealing steel, especially sheet steel without reheating, which comprises taking the steel plates at the end of the rolling operation while still retaining a temperature of 930 to 1290 degrees Fahr. (500 to 700 degrees Cent.) and stacking these plates in a slow cooling pit until a suitable number of plates have been superposed, then closing the pit and permitting the stack of plates to cool slowly for 20 to 48 hours. In this way the mass comes to a uniform temperature throughout, rolling and mechanical strains are eliminated, and a normalized plate having the usual annealed properties is produced without the expensive reheating and without the objections to the reheating operation.

1,539,260, Acid-Resistant Alloy, Charles B. Jacobs, of Wilmington, Delaware, assignor to E. I. Du Pont De Nemours & Company, of Wilmington, Delaware, a corporation of Delaware.

This patent describes an acid-resistant alloy, composed mainly of copper and silicon and containing a sufficient amount of manganese to render the alloy machinable and workable. Various compositions of copper and silicon may be used containing 82 to 96 per cent of copper and 3 to 15 per cent of silicon, with an amount of manganese sufficient to render the alloy workable.

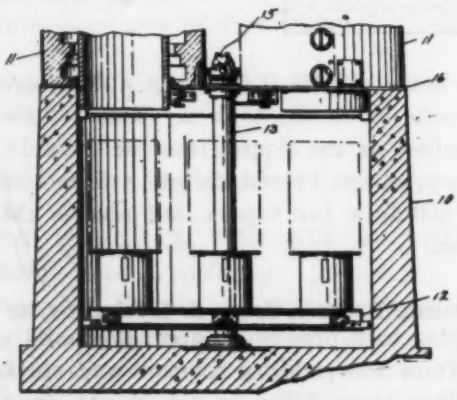
1,539,456, Iron Alloy, Wesley J. Beck and James A. Aupperle, of Middletown, Ohio, assignors to the American Rolling Mill Company, of Middletown, Ohio, a corporation of Ohio.

This patent describes an alloy capable of resisting repeated heating to a

high temperature and cooling in air without scaling. The alloy is particularly adaptable for annealing boxes, distillation apparatus, stoves, etc. It comprises the ordinary mild steel, to which 2 to 4½ per cent of silicon has been added. The upper limit of silicon should be below that which renders the alloy unworkable. An alloy containing 2 to 4½ per cent of silicon may be repeatedly heated to a temperature of 1650 degrees Fahr. (900 degrees Cent.) or thereabout, and recooled without forming a scale which chips off, or without losing weight or deteriorating in the treatment. Smaller percentages of silicon may be used but with less desirable results.

1,539,848, Furnace, Charles F. Kenworthy, of Waterbury, Connecticut, assignor to Charles F. Kenworthy, Incorporated, of Waterbury, Connecticut, a corporation of Connecticut.

This patent describes an annealing furnace consisting of a rotating turret mounted in a pit 10 upon a hydraulically operated carriage 12. Above the pit is a plurality of annealing chambers 11, and spaced evenly therewith



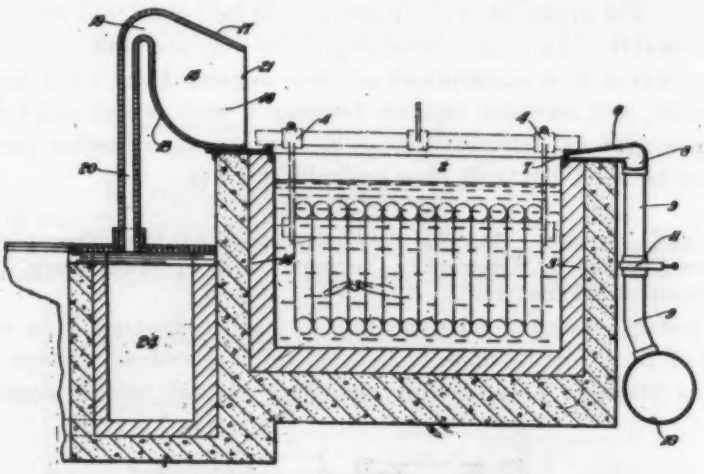
are charging stations. In operation of the furnace the table 12 is raised under hydraulic pressure to insert the articles on the table to be annealed in the annealing chambers 11 and to bring the articles which have just been annealed up to the charging platforms and after the proper annealing period the table is lowered and automatically rotated by means of a cam arrangement 15 located at the head of the central column 13 to move the charged tables into a position beneath the furnaces and to move the annealed product into a position beneath the charging chambers. The novelty of the apparatus consists in the location of the cams which cause rotation of the table 12 in the accessible position at the top of the furnace, as indicated at 15.

1,539,973, Fume Collecting and Removing Apparatus, Edward L. Truxal, of Wilkinsburg, Pennsylvania, assignor to the American Steel and Wire Company of New Jersey, a corporation of New Jersey.

This patent is for a fume and vapor removing apparatus, for removing fumes from pickling vats or the like.

In the sketch, 2 indicates the pickling vat containing the hot acid or other pickling solution, in which the rods 3, suspended on the carrier 4, are inserted for cleaning the same. At one end of the vat 2, a plurality of

nozzles 6 are provided, having orifices 7 in close proximity and extending along the entire edge of the vat 2. The nozzles 6 are connected by means of a pipe 9 and valve 11 to a blower manifold 10, by which compressed air may



be forced through all the nozzles 6 to sweep a continuous sheet or jet across the surface of the solution in the tank 2. This jet sweeps away the vapors arising from the surface of the liquid, into the hood 15, where they rise and pass out through the openings 19 and 20 into a tunnel 24 which may be under suitable suction to withdraw the vapors and remove them to a point remote from the pickling vat.

1,540,022, Annealing Process, Irvin J. Koehnline, of Bridgeport, Ohio. This patent relates to a process of annealing mild steel sheets which are ordinarily removed from the pickling solution and stacked while still wet in annealing boxes. When these damp or wet sheets are annealed in the usual way in sealed boxes, the water becomes quickly converted into steam and as the temperature rises the hot steel decomposes the water in accordance with equation

$$Fe—H_20=FeO—H_2,$$

so that the ferrous oxide coats the surface of the steel and the hydrogen under pressure in the annealing box becomes more or less dissolved or occluded in the metal and produces the so-called "smoky edges" which resist the subsequent acid cleaning and produce mottled or cloudy areas on the steel which do not tin evenly and cause a great amount of waste. These objections may be overcome according to the patent by slowly heating the annealing boxes containing the wet sheets for two hours or more at a temperature sufficient to vaporize the water, but insufficient to cause the metallic iron to decompose the water. The water vapor or steam formed in this heating is permitted to escape freely and may be removed from the boxes by suction. After the water vapor has been driven off at this slow heat ranging between 390 to 1112 degrees Fahr. (200 to 600 degrees Cent.) the heat may be increased to properly anneal the sheets. The removal of the water vapor prevents the objectionable reaction above described.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

PRINCIPLES OF METALLURGY OF FERROUS METALS FOR MECHANICAL ENGINEERS. By Leon Cammen, associate editor, *Mechanical Engineering* in *Mechanical Engineering*, Vol. 47, No. 5, May, 1925, page 339.

The above is the first of a series of articles discussing the underlying physical and chemical processes involved in the metallurgy of iron and steel, and dealing particularly with the physico-chemical properties of iron alloys. The second part, which appears in the June issue of *Mechanical Engineering*, deals with the crystalline structure of ferrous metals.

REJUVENATING WORN CUTTING TOOLS. In *American Machinist*, May 28, 1925, page 849.

This article tells how a Detroit shop is saving money for manufacturers by reconditioning worn cutters, drills and reamers.

DEVELOP NEW FURNACE FOR STEEL AND IRON FOUNDRY SERVICE. In *Foundry*, June 1, 1925.

This article states that the electric melting furnace which was designed principally for melting steel has been modified and improved by various makers in recent years and now is used quite extensively in melting non-ferrous metal in addition to iron and steel. The latest design of electric furnace for melting steel and iron has been recently erected and placed in operation in the foundry of the Bingham and Taylor Company, Buffalo, N. Y. The basic features and general apperance of this furnace do not differ materially from other electric furnaces at present on the market; however, the general construction features and operating mechanism differ considerably.

EXPORT OUTLOOK PICTURED BRIGHT. In *Iron Age*, May 21, 1925, page 1499.

At the Fifth Foreign Trade Conference, held in Cleveland on May 12, 1925, under the direction of the Cleveland Chamber of Commerce, Europe's position, especially of Germany, as well as the common American attitude were discussed. Addresses were made by four representatives of the bureau of foreign and domestic commerce of the department of commerce, and round table discussions were held, during which export advertising, export merchandizing and export credits were discussed.

"DIRTY STEEL" UNDER THE MICROSCOPE. By G. F. Comstock, metallurgist, Niagara Falls, N. Y., in *Iron Age*, April 23, 1925, page 1185.

The author discusses the precautions necessary in preparing and judging

specimens, and states that rusting, pitting and scratches may be misleading. A number of photomicrographs of specimens are given.

PAPERS PRESENTED AT MEETING OF AMERICAN SOCIETY OF MECHANICAL ENGINEERS, MILWAUKEE, May, 1925.

I. E. Mountrop and E. W. Norris, Boston, presented a paper entitled "The X-Ray Examination of Steel Castings," which discusses one of the latest methods in the use of X-Rays. "Defects in Large Forgings," was given by J. Fletcher Harper, Milwaukee, and describes some of the common defects encountered, and their causes. Methods used to insure uniform and homogeneous material are also included. "Aluminum and Its Light Alloys," was the title of another paper presented by R. L. Streeter and P. V. Faragher, Pittsburgh, which gives data on the mechanical properties of alloys for sand, permanent-mold, die castings, wrought aluminum, high-strength alloys and forgings therefrom.

CHROME SURFACES ELECTROLYTICALLY DEPOSITED. By Colin G. Fink, Columbia University, New York City, in *Forging-Stamping-Heat Treating*, June, 1925, page 202.

The author of this article states that chromium plating will give the manufacturer an opportunity to discard high priced alloys where resistance to heat, corrosion and wear are desired.

SOME FATIGUE TESTS ON NON-FERROUS METALS. By R. R. Moore, chief of physical testing branch, material section, engineering division, air service, McCook Field, Dayton, Ohio.

This paper was presented at the June meeting of the American Society for Testing Materials at Atlantic City, and gives the results of endurance tests on pure magnesium, aluminum, a forged and cast magnesium-aluminum alloy, and naval brass. An improved type of rotating beam machine of wide range of use is also described.

POWER PRESSES—THEIR USE IN INDUSTRY. By E. V. Crane, staff engineer, E. W. Bliss Company, Brooklyn, N. Y., in *Forging-Stamping-Heat Treating*, June, 1925, page 213.

The above paper was presented before the Providence Engineering Society and the author states that for duplicate production of metal parts in large quantities, there are few if any general types of tools which compare favorably with power presses. Numerous applications are described in detail.

OBSERVATIONS OF MARTENSITE AND TROOSTITE. By J. H. Whiteley.

This paper was presented at the annual meeting of the Iron and Steel Institute, London, May, 1925. The observations recorded in this paper have been made during an investigation, the purpose of which was to trace the origin of the different structures grouped under the term martensite. As the work progressed, it became obvious that before any results could be given, the formation of troostite would also have to be considered. The study has been confined to the microscopic examination of quenched specimens.

News of the Chapters

STANDING OF THE CHAPTERS

IN the June issue of TRANSACTIONS appeared a relative membership standing of the 29 chapters of the Society as of April 1, 1925, and as of May 1, 1925. The tabulation which appears below shows the relative membership standing of the chapters on May 1, 1925, and on June 1, 1925.

GROUP I. Detroit still heads group 1, this time by about 25 members.

Standing as of June 1

I	II	III
1. Detroit (331)	1. Hartford (126)	1. Tri City (64)
2. Cleveland (305)	2. Lehigh Valley (101)	2. Rochester (62)
3. Pittsburgh (284)	3. Golden Gate (96)	3. Los Angeles (60)
4. Chicago (267)	4. Cincinnati (78)	4. Washington (52)
5. Philadelphia (263)	5. Syracuse (73)	5. New Haven (52)
6. Boston (224)	6. Milwaukee	6. Schenectady
7. New York (206)	7. St. Louis	7. Worcester
	8. Indianapolis	8. PROVIDENCE
	9. Buffalo	9. Rockford
	10. Northwest	10. TORONTO
		11. Springfield
		12. South Bend

Standing as of May 1

GROUP I	GROUP II	GROUP III
1. DETROIT (298)	1. Hartford (127)	1. Tri City (68)
2. Cleveland (297)	2. Lehigh Valley (108)	2. Rochester (62)
3. Pittsburgh (275)	3. Golden Gate (102)	3. Los Angeles (60)
4. Chicago (266)	4. CINCINNATI (74)	4. WASHINGTON (52)
5. Philadelphia (255)	5. Milwaukee	5. New Haven
6. Boston (229)	6. Syracuse	6. SCHENECTADY
7. New York (209)	7. ST. LOUIS	7. Worcester
	8. Indianapolis	8. Rockford
	9. Buffalo	9. Providence
	10. Northwest	10. Springfield
		11. TORONTO
		12. South Bend

All of the other chapters in this group remain practically the same, with the exception of New York which shows a slight gain.

GROUP II. This group remains the same as in the previous report except that Syracuse moves ahead of Milwaukee.

GROUP III. The third group had but one change, although New Haven and Washington are tied in fourth place with 52 members each, while Providence passes Rockford, for eighth place, and Toronto advances to tenth place ahead of Springfield.

There were 112 new and reinstated during the month, while 46 were dropped for non-payment of dues, 11 resigned and 3 deaths, leaving a net gain of 52. Several chapters suffered heavily from arrears, Lehigh Valley losing 8, Chicago 5, Philadelphia 4 and Detroit 4.

BOSTON CHAPTER

The following is the report of the annual meeting of the Boston chapter held Friday, May 22, at the Walworth Mfg. Co., South Boston.

A plant visitation was arranged for 3:30 p. m. wherein about 75 members and guests of the Boston chapter inspected the Walworth Mfg. Co. plant at South Boston, visiting all the various departments. The Walworth Mfg. Co. supplied each guest with a ribbon badge appropriate to the occasion, and following the visit a band concert was given by the Walworth band. One of the interesting heat treating installations shown was a new continuous recuperative electric furnace used for annealing vise jaws.

Dinner was served at the plant followed by the annual business meeting. S. W. Parker, chairman of the program committee, outlined the plans for the June outing which included a boat trip to Pemberton Inn, a shore dinner, athletic sports and entertainment for Saturday, June 13th.

The next business was the secretary's report and a review of the meetings held during the year was read. Membership to date showed a healthy increase over last year, there being a membership of 248, or an increase of 73 members, which, in view of the usual reaction to follow a convention, was felt to be very satisfactory by the secretary. There was a total of nine meetings held during the year with an average attendance of approximately 75. The new projects entered into were the printing and issuing of a year book, listing all the membership, also the printing of a program in advance.

The next business was the election of officers, and the following officers as nominated were unanimously elected: Chairman, J. M. Darke, metallurgist, General Electric Company, West Lynn, Mass.; vice-chairman, F. H. Cole, metallurgist, Walworth Mfg. Co., South Boston; secretary and treasurer, H. E. Handy, metallurgist, Saco-Lowell Shops, Lowell, Mass.

Committees—Program: L. D. Hawkridge, Hawkridge Bros. Co., Boston; H. B. Parker, Dr. W. S. Williams, H. B. Briggs. Membership: G. C. McCormick, Crucible Steel Co.; W. J. Kunkel, R. J. Johnston, J. R. Pounds. Attendance: E. H. Fernold, Saco-Lowell Shops; Mr. Morresey, D. R. Fiske, E. L. Reed. Reception: C. L. Stott, General Electric Company; G. C. McCormick, J. H. Zimmerman, A. D. Bach, Jr. Technical Library: V. O. Homerberg, Massachusetts Institute of Technology, I. N. Zaverine, Z. L. Sault, E. R. S. Reeder. Employment: G. C. Davis, Heat Treating Equipment Co.; L. G. Bean. On to Cleveland Committee: F. H. Cole.

The chairman of the committees will be the three officers to make up an executive committee. There were two new business committees formed,

namely: technical and library committee whose plan is to review available information at the libraries of our city and submit this information to the chapter members, also to make recommendations to have questions submitted in writing to the committee which are to be answered during the regular meetings. It is felt that this plan can be worked out since there need be no diffidence about asking questions as the inquirers' name will not be mentioned.

The other new committee is the employment committee which the secretary has attempted in a small way to do during the past year. This committee in co-operation with the national office will list members desiring employment and perform the usual duties of an employment bureau.

Following this business meeting an address of welcome was given by Mr. Hart, Supt. of the Walworth Mfg. Co. Mr. Hart referred briefly to some of the history of the Walworth Co., stating that in 1871 Mr. Walworth, founder of this company, conceived the idea of heating buildings by passing steam through pipes. The first steam heating system was installed in a local manufacturing plant. Means of communication between the company's Boston office and their Cambridge plant at that time was by telegraph which was considered to be an efficient method as there were few plants which even had that. Mr. Edison, during his experiments with the telephone, obtained and received permission for the use of this wire between the Walworth Mfg. Company's office and plant in Cambridge for the first telephone communication.

The main speaker of the afternoon was F. R. Palmer of the Carpenter Steel Co., Reading, Pa., who gave an illustrated lecture on "Giving Steel Tools a Chance." This talk was one of the most interesting and valuable ever presented before the Boston chapter. Mr. Palmer covered the practical and usual problems to be met with in tool manufacture from the standpoint of design, hardening, machining and grinding, illustrating many of the conditions explained with stereopticon pictures of actual instances. He pointed out that the life of tools depended upon its analysis, quality and heat treatment, and that "a piece of hardened tool steel possesses so much strength depending upon its analysis, quality and heat treatment and when the total of its internal strains reaches the critical point it fractures." A very lively and interesting discussion followed this talk, and many requests were made that Mr. Palmer have this paper published in TRANSACTIONS for the benefit of all the members.

G. C. Davis.

Following is a report of the June outing of the Boston chapter held on Saturday afternoon and evening, June 13th, at Pemberton.

About seventy-five members of the Boston chapter gathered at the wharf, leaving by boat at 2: 15 for Pemberton where they were conducted directly to the Hotel Pemberton.

The first event of the afternoon was the ball game between the Reds and the Blues, the Reds captained by V. O. Homerberg and the Blues by G. C. Davis. Before assembling on the boat, badges were distributed to the members, being of two colors, blue and red and equally divided, and these badges designated which team the member belonged to. Naturally, since the writer

was the captain of the Blues team, the Blues won by approximately 115 to 2.

The next event was a tug-of-war which, of course, the Blues won.

The next event was a series of races including a pipe race, wherein the contestants ran to one spot and obtained a pipe, then to another spot where they filled it with tobacco, and a third spot where they lit it and raced home. Also, there was the usual three-legged race and fat man's race. Prizes were given for these last three events.

Following the sports, every one was in condition to enjoy a swim in the salt water pool heated to 60 degrees and gathered thereafter on the piazza of the hotel where the Agony Quartet held full sway until dinner was served.

A Shore Dinner was served in the private dining room at 6:30 which consisted of steamed clams, fish chowder, broiled lobster, ice cream and coffee.

An attractive vaudeville entertainment followed the dinner in the dining room. A few took advantage of the optional trip to Paragon Park, an amusement park; following this entertainment the majority returned to Boston on the same boat where the Agony Quartet held full sway. *G. C. Davis.*

BUFFALO CHAPTER

On May 25, 1925, the Buffalo chapter of the society held its regular monthly meeting. The meeting was called to order at 8:30 by chairman Mr. Armstrong, and the minutes of April 27th meeting were read and approved.

S. P. Rockwell, the inventor of the Rockwell testing machine, was present and spoke a few minutes on the "Dilatometer" system of heat treating. The system registers the critical range by the use of a silicon rod which does not expand and a recording device. The steel has a different expansion ratio as it passes through the critical range.

A. H. D'Arcambal of the Pratt and Whitney company was the principal speaker, the subject being "carbon steel and high speed steels used in the manufacture of small tools and metallurgical control." A number of the carbon steels and tungsten steels were described in detail, giving the chemical analysis, the uses, and heat treatments.

A number of slides were shown which would be very helpful in selecting the steel for stock. Carbon steels which are annealed to Brinell about 170 seem to be best for average use. The deep etching of steels was also mentioned for inspecting the steel for stock.

With tungsten steels, the carbon content is the most important, and this should be 0.65 to 0.75 per cent.

After the address, a very large number of specimens were passed around and the usual discussion of various problems followed.

The meeting was very interesting, and attended by 110 members and guests.

The June 12th meeting of the chapter was called to order at 8:30 p. m. by G. J. Armstrong. The minutes of the May 25th meeting were read and approved. The treasurer's report was presented and approved. The following committee was previously appointed by the chairman for the purpose of nominating officers for the coming year: W. H. Blocksidge, David Bell and W. S. Miller. The committee gave a report of nominations and the

following members were unanimously elected to hold office for the coming year: chairman, G. J. Armstrong; vice-chairman, Fred G. Brost; secretary-treasurer, B. Clements.

Executive Committee: W. H. Blocksidge, W. S. Miller, O. W. Mueller, F. B. Lounsberry, David Bell, B. L. McCarthy.

CHICAGO CHAPTER

The Annual Outing and Athletic Carnival of the Chicago chapter was held at Dixmoor Golf Club, June 13, 1925. At two o'clock a large attendance sat down to a chicken dinner served in the club house. During the dinner exceptionally good entertainment was furnished by the Ingersol-Shepard orchestra who donated their greatly appreciated services for the occasion.

Three-thirty found everybody out on the grounds where they participated in and were amused by a larger number of contests including a tug-o-war between picked teams, a fat man's race, standing broad jump, horseshoe pitching contest, and indoor baseball. Valuable prizes for the winners were donated by:

W. R. Mau, district manager, Vanadium-Alloys Steel Co.; C. M. Cunningham, Crucible Steel Company of America; Claude S. Gordon, of Claude S. Gordon Company; E. H. Pasmore, Chicago Mgr., Columbia Tool Steel Co.; Alfred Ford, Supt. Chicago Nipple Manufacturing Co.; R. R. Smith, sales metallurgist, United Alloys Steel Co.

A new and promising feature added to the annual affair was a Handicap Golf Tournament in which nine foursomes had entered to compete for a mammoth loving cup presented by Harry "Q-Alloy" Harris, General Alloys Company, Boston. The first foursome teed-off at 3:55 and by 7:30 the last had completed the eighteen holes. The loving cup, which must be won three times to become the permanent property of the holder, went to J. B. Mudge, metallurgist, Western Electric Company. Second place honors were won by W. G. Tarnow of the Goss Printing Press Company who was presented with a dozen picked golf balls by J. H. Hinkley, Chicago manager of the Halcomb Steel Co. R. G. Guthrie, metallurgist, People's Gas Light & Coke Co., won a stainless steel putter donated by W. A. Edwards, district manager, Ludlum Steel Company, for the third prize. Herman Shultz, superintendent, electric furnaces, Illinois Steel Co., took the fourth prize of a half dozen stainless steel knives, also presented by W. A. Edwards. The booby prize went to Mr. Scheuch, metallurgist, Western Electric Company, who received an incarnated idea of H. H. Harris in the form of a self-adjusting, flexible, non-skid, et cetera, golf club.

The officers wish to take this opportunity to thank everybody who by their services or donations did so much to make this outing the success it was.

P. S. If you want to meet a steel man in a playful mood, meet him at one of these annual outings. *J. A. C.*

CINCINNATI CHAPTER

The following officers and executive committee were elected at the May meeting of the chapter: chairman, E. P. Stenger; vice-chairman, W. R. Klinkicht; secretary-treasurer, F. L. Martin.

Executive Committee: J. C. Hartzell, C. M. Bigger, J. H. Nead, E. F. Ries, Edward Gardner. *F. L. Martin.*

CLEVELAND CHAPTER

The election of officers of the Cleveland chapter for the coming year was held at their May 15th meeting and the following were elected: chairman, H. A. Schwartz; vice-chairman, H. H. Smith; secretary-treasurer, A. S. Townsend.

Executive Committee: G. I. Allen, A. E. Buelow, A. H. Frauenthal, Raymond Rolf, T. C. Sherman, J. D. Sterling. *A. S. Townsend.*

DETROIT CHAPTER

The April 20th meeting of the Detroit chapter was held in the General Motors Building and, following a short business meeting, L. W. Heiser of the Ford Motor Company, gave an interesting talk on "Practical Problems in the Heat Treatment of Steel, and the Installation of Heat Treating Equipment." Mr. Heiser described in considerable detail the heat treating equipment which is being used in the Highland Park plant of the Ford Motor Company, in which they have adhered to the push-type or continuous conveyor type of furnace for both their annealing and heat treatment work. He said that their furnaces consisted of one type for normalizing, one type for quenching, one type for drawing and one type for annealing. Their carburizing furnaces are composed of three different compartments, the heating chamber, soaking chamber and the cooling chamber. These furnaces are equipped with steel rails and are capable of carrying a load of 8 or 9 tons. Every 15 minutes two boxes are inserted into the furnace and two are taken out from the other end. These furnaces are also the push-type. The speaker described their method of quenching camshafts wherein the heated camshafts are placed on three rollers and the whole fixture rolls back into the quenching water. While quenching is in operation, these rollers turn the shaft and keep it straight. He pointed out, however, that they are experiencing some difficulty in keeping these shafts straight during and after the tempering heat. He said their crankshafts are quenched in this same general way as are also the rear axle shafts and drive shafts. The camshafts are quenched in a perpendicular spindle hung mounted on roller. The door is closed by compressed air and the water is applied from all sides, and thus spins the crankshafts. The speaker said that they did not use recuperators on their furnaces. In answer to the question as to whether or not the Ford Company normalized all of their steels, Mr. Heiser replied that all of their gear blanks were normalized, but that their crankshafts were not. In discussing the steel which is used in the manufacture of camshafts, the author stated that they do not carburize their camshafts, but instead are using a 0.35 to 0.40 per cent carbon steel with 0.70 to 0.90 per cent manganese in which it is possible to get a Brinell hardness value between 500 and 600. These camshafts are quenched at 1470 degrees Fahr. in cold water. In respect to the heat treatment of gears, Mr. Heiser pointed out that due to the fact that they did not grind the teeth of their gears, it is necessary that they be held as nearly to the correct size as possible, therefore the use of an electric furnace is not suitable, due to a certain amount

of scaling. These parts are heated in cyanide and are quenched in oil and tempered in an oil-fired furnace. In answer to the question as to the reason his company is changing over to electric furnaces, the speaker said that he believed that electrical heat was considerably cheaper than fuel. In closing, Mr. Heiser extended an invitation to all present to visit the Highland Park plant and inspect their heat treating room and especially their large continuous carburizing furnaces.

At the meeting of the chapter held on May 16, Dean Cabot, Dean of the University of Michigan Medical School, spoke to the members. He related in an interesting and humorous manner his experiences during the war. Mr. Macon of the *Iron Age* had been scheduled to talk at this meeting, but due to the illness of one of his associates, was unable to be present. Professor Hobbs, professor of geology at the University, then spoke to the members on earthquakes, which talk was also very interesting. The chairman of the meeting, W. E. Jominy, then called upon Professor E. D. Campbell, who expressed his appreciation and delight that the meetings of the local chapter were being held at the University this year, and said he was glad that he was able to be present. A rising vote of thanks was then extended to the speakers of the evening.

Meeting: Steel Treaters' Revue, June 13, Prince Edward Hotel, Windsor, Ontario.

New officers for the coming year are as follows: chairman, W. G. Calkins; vice-chairman, Lawrence Thomas; secretary-treasurer, Robert Atkinson.

Executive Committee: Harry Martin, H. L. Shippy, W. H. Graves, Carl Nilson, F. P. Zimmerli.

GOLDEN GATE CHAPTER

The annual meeting of the Golden Gate chapter was held on May 13th in the form of a dinner at the New Peerless Cafe, Oakland. As we have come to expect, the meeting was well attended, there being sixty-two present.

The meeting was called to order by F. H. Pelle, vice-chairman, owing to the absence of P. L. Bannan, the chairman, due to illness. After the regular business of the meeting had been transacted, the secretary presented the apologies of the absent chairman, who felt it a particular misfortune not to be present at the last meeting of his term of office. Mr. Bannan also wished to express his appreciation of the loyalty with which the executive committee and other officers had responded to his requests for action, and also to the various appointed committees for their work throughout the year. The secretary then gave a short resume of the history of the chapter for the benefit of the new members and guests, and, finally, made his report on the finances of the chapter for the year ending that night.

A rising vote of thanks was given in honor of Mr. Bannan's chairmanship.

The acting chairman thereupon called upon the spokesman of the nominating committee, S. R. Thurston, to deliver their report, which Mr. Thurston did with appropriate comments on the slate drawn up. The motion was then made by T. S. Hutton that the nominations be closed, which he elaborated

with individual tributes to the names suggested. This was followed by the election, in which the slate proposed by the nominating committee was unanimously approved.

The officers elected were as follows: Chairman, Frank B. Drake, Johnson Gear Company; vice-chairman, E. Downing, president, Hoover Spring Company; secretary-treasurer, D. Hanson Grubb, Pacific Scientific Company.

Executive Committee: A. N. Armitage, metallurgist, Columbia Steel Corporation; P. L. Bannan, president, Pacific Gear & Tool Works; Prof. A. B. Domonoske, associate professor, University of California; E. E. Jamison, president, Jamison Steel Company; C. S. Moody, metallurgist, C. L. Best Tractor Company; H. S. Taylor, metallurgist, Holt Manufacturing Company; H. C. Venter, Supt. of shops, Southern Pacific Co.; H. H. Whiting, president, Best Steel Castings Company; F. L. Wight, representative, U. S. Steel Products Company; R. T. Wise, Standard Die & Specialty Co.

The regular business of the evening was then resumed, and the chairman called on C. S. Sorensen of the Security Manufacturing Company of Los Angeles for a few words on conditions in the South. Mr. Sorensen had some interesting remarks to make concerning his company's work, and thereafter answered several questions.

The next event was the talk by E. E. Jamison of the Jamison Steel Company on "Carburizing," being Number six of the series on Steel. The talk was most interesting and was followed by a number of questions and much discussion, showing the vital interest of the members in this phase of their work.

S. R. Edwards was then called upon for an informal discussion of the variations in gear making practice in the East, with particular reference to the automotive industry. Since Mr. Edwards was for some time metallurgist for the Muncie Gear Division of the General Motors Corporation, he was well qualified to handle this subject.

The meeting did not close until late, due to the general interest of those present in the various subjects under discussion, and the repeated questions and discussions. *D. Hanson Grubb.*

The June meeting of the Golden Gate chapter was held last night, the 10th of June, at the Engineers Club, San Francisco. The date was advanced a few days due to the imminent departure of one of the speakers on an eastern trip, and the notice given was very short. Notwithstanding this fact, the attendance was excellent, and the meeting a most enthusiastic one—an excellent send-off for the newly installled officers.

Frank B. Drake, the new chairman, presided and made a few brief remarks on the plans being formulated for the coming year. Mr. Drake has just returned from the East where he has been in touch with the work of the eastern chapters, and we anticipate a very active winter.

The first speaker of the evening was Edward J. Fowler, president of the Pacific Foundry Company, who gave a most interesting and well received talk on "Some Problems in Connection with Cast Iron." Mr. Fowler's connection with the foundry business is a life-long one, and the members could have listened to him with pleasure for several times the period he was confined to.

A talk on "Testing Machines," by Professor A. B. Domonoske of the Department of Mechanical Engineering at the University of California, followed, being the current part of the series of lectures on steel. It was illustrated by slides and followed by an animated discussion.

Considering the vacation period, the meeting was very well attended—there being over sixty present. *D. Hanson Grubb.*

HARTFORD CHAPTER

On June 9, 1925, the Hartford chapter held its annual banquet at the City Club with an attendance of 105.

During and after the dinner we were entertained by singing and dancing girls in a good vaudeville performance.

F. G. Hughes, vice-president of the New Departure Mfg. Co. and a director in our national society acted as toastmaster. Brief reports of the year's events and of the standing of the chapter were given by the past chairman and the treasurer.

W. B. Bailey, economist for the Travelers Insurance Co., gave an interesting talk "A Picture of the Peripatetic" in which he described the life and habits of the American vagrant, a subject to which he has devoted several years study, actually living the life of a hobo for this time.

On Saturday, June 13th, the Hartford chapter joined the Hartford Engineers Club in an outing and sheep bake at Goodwin Park. Our baseball team defeated that of the A. S. M. E. by a score of 13 to 12. In refereeing the African Elimination Contest, A. H. d'Arcambal overexerted himself causing a slight accident to his clothing, more embarassing than painful.

A good time was enjoyed by all.

E. D. Lambert.

LEHIGH VALLEY CHAPTER

The following officers and executive committee members were elected by the chapter for the coming year at their meeting on May 21, 1925: chairman, B. F. Shepherd; vice-chairman, F. R. Palmer; secretary-treasurer, R. H. Christ.

Executive Committee: G. C. Lilly, W. L. Trumbauer, J. W. Herb, E. B. Shimer, W. R. Shimer, C. C. Sickles, A. E. Fowler, G. O. Carlson, L. J. MacGregor. *B. F. Shepherd.*

LOS ANGELES CHAPTER

The Los Angeles chapter of the A. S. S. T. held its regular monthly meeting on May 6th in the conference rooms of the Westinghouse Electric Co. Mr. Laury, retiring chairman of the local chapter, gave a brief resumé of the chapter activities during the past year and urged the members to continue the good work in building a bigger and better chapter. The retiring chairman then presented to the members the following newly elected officers: C. A. Stiles, Lacy Mfg. Co., chairman; Charles Drenk, Axelson Machine Co., vice chairman; E. C. Black, Baker Iron Works, secretay-treasurer. Exectuive Committee: W. H. Laury, Axelson Machine Co.; Wade Hampton, Hughes

Tool Co.; W. C. Hartman, Union Tool Co.; G. C. Nelson, Firth Sterling Steel Co.

A short talk by the new chairman, briefly outlining the plans for the ensuing year, reading of the annual report by the secretary and the self introduction of the guest speaker of the evening, E. C. Claussen of the Johns Manville Co.

Mr. Claussen addressed the chapter on the subject of "Refractories" and discussed the topic in a highly interesting manner. Starting with a description of clay deposits, types of clays and their manufacture into bricks, illustrating his talk with many samples of clays, brick and bonding materials. The speaker gave his audience much data of value relating to costs of refractories, their relative values, proper installation and subsequent care. The topic was particularly opportune, following a recent meeting in which the subject of "Furnace Design" was handled.

A lively discussion followed when the speaker had finished, and the many times he had to rspond to questions was good evidence that the topic was well chosen. The discussion brought out suggestions and ideas sufficient for another good meeting on the same topic.

Through the efforts of Prof. Clapp and his student assistants, of California Institute of Technology, tracings and printed data relating to the tests of steels, made during the April meeting of the chapter were available. Blue prints and data were distributed to the members to be studied and brought to the June meeting, at which time Mr. Laury will give a talk on the purposes and results of these tests. In additon to Mr. Laury's talk the chapter will be addressed on the subject of "Tool Steels" by Mr. Jamison of the Jamison Steel Co.

The May meeting had a splendid attendance, fifty-six members and guests being present. A number of guests signified their intention of becoming members, and announcement was made that the chapter is due to add several sustaining members. As a happy climax to a successful meeting, Mr. Lee, of the Westinghouse Co., presented to the chapter members several dozen attachments for use on the bases of telephones which he guaranteed would tame telephones that have a tendency to walk around on the desk. During an intermission an excellent luncheon was served in the cafeteria of the Westinghouse Co. as a treat from the chapter to its members. Much gratitude is due the Westinghouse Co. for the splendid treatment they have accorded the Los Angeles chapter. *C. A. Stiles.*

The Los Angeles chapter meeting was postponed one week owing to the Shrine Convention, and was held on June 10 in the office of the Westinghouse Electric & Manufacturing Company. Chairman Stiles called the meeting to order at 7:45 p. m., and after the regular order of business, W. H. Lawry spoke briefly on various methods of physical testing and described in detail various test specimens which have been used in a previous demonstration held in the laboratory of the California Technical School, Pasadena. The speaker of the evening, E. E. Jamison of the Jamison Steel Co., San Francisco, was then introduced and addressed the chapter very ably on the subject of the manufacture of alloy and high speed steel.

The Steel Treaters were afforded a real treat as the subject was interesting and instructive. After a general discussion, the meeting adjourned.

E. C. Black.

NEW HAVEN CHAPTER

Annual Dinner, June 26, Wilcox Pier Restaurant, Savin Rock Park. Shore Dinner and Entertainment.

The following officers have been elected for the coming year: chairman, E. L. Wood; vice-chairman, J. H. G. Williams; secretary-treasurer, W. G. Aurand.

Executive Committee: J. Brooks, T. Besom, W. H. Duley, E. C. Richardson, A. E. Bellis, C. F. Hammond, J. W. Black, H. C. Goodwill, F. J. Dawless, M. E. Gere, H. G. Keshian, L. T. Perry.

PHILADELPHIA CHAPTER

The last chapter meeting preceding the Summer vacation was held on Friday evening, May 27th. The meeting was preceded by the usual "Get Together" dinner at the Engineers' Club and about fifty members were present, which was a goodly number considering the oppressive heat and the season. Although this was the last meeting of the year, it was nevertheless one of the most important ones held, as the new officers for the coming year were elected and installed.

The following officers were elected: chairman, Arthur L. Collins; vice-chairman, Theodore Wiedemann; secretary-treasurer, A. E. Donovan.

Directors: H. C. Knerr, Dr. George L. Kelley, A. W. F. Green, N. C. Einwechter, John P. Brown.

The members of the chapter feel especially grateful to the retiring officers—particularly to the retiring chairman— H. C. Knerr, and the retiring secretary-treasurer—A. W. F. Green, for their zealous work during the past year.

The course in Metallography given at Temple University, under the able guidance of Mr. Knerr, was brought to a successful conclusion for the year by an exhibition of the students' work at the University on the evenings of June 15th and 16th. Even bigger things are looked for in the course which will be continued next year.

Theodore Wiedemann, the efficient chairman of the Library Committee, succeeded—by a most clever and unique method—in augmenting the library fund to the extent of $66.00 at this meeting. Mr. Wiedemann will be glad to explain his fund-raising method to any of the other chapters that may be interested.

Believing in the old saying—"all work and no play makes Jack a dull boy", the meeting was delightfully entertained by an excellent male quartette.

A. E. Donovan.

PITTSBURGH CHAPTER

The Pittsburgh chapter held its June meeting in the Fort Pitt Hotel on the evening of June 2nd.

After a short business session, President McMillen introduced J. W.

Hacker who gave the paper of the evening. Mr. Hacker, who is superintendent of the by-product coke plant of the Pittsburgh Crucible Steel Company at Midland, Pa., chose as his subject, "The By-product Coke Oven as an Integral Part of the Steel Works."

Mr. Hacker first recounted the history of the coke and iron industry and then told of the development and growth of the use of by-product ovens. He told many interesting incidents of his experience when introducing some of the newer equipment.

In describing the construction of the ovens, an interesting item was that there are over three hundred shapes and sizes of silica brick used. The brick must be so exactly made and put together that they will be gas tight at working temperature.

As an indication of the increased efficiency, he said that there had been a reduction of from 4 to 5 man-hours per ton of coke produced to one man-hour per ton.

Then followed a number of very interesting pictures of the construction and operation of the by-product ovens with the equipment used in separating the by-products.

At the conclusion of Mr. Hacker's interesting talk, there were a number of questions asked and then refreshments were served to allay the effect of the heat of the evening. After this several motion picture comedies were shown depicting the bathing beach and the bathers as a further inducement to forget the hot weather which prevailed.

The meeting then adjourned for the summer. *H. A. Neeb, Jr.*

RHODE ISLAND CHAPTER

The executive committee of the chapter for the coming year is as follows: chairman, John E. Wiggins; vice-chairman, Thomas Wray; secretary-treasurer, Carl G. Peterson. Members of the committee are; F. H. Franklin, A. H. Annan, O. W. Geer, John E. Hull, C. M. Frietag, E. J. Sullivan, S. N. Welch and H. F. Cummings.

C. G. Peterson.

SPRINGFIELD CHAPTER

The Springfield chapter of the Society held a meeting on May 19h in the Chamber of Commerce Building at 8 p. m.

V. O. Homerberg of the Massachusets Institute of Technology, Cambridge, Mass., gave a very interesting talk, illustrated by lantern slides describing the various micro-constituents of steel.

Mr. Homerberg began his talk by demonstrating the equilibrium diagram for carbon steel and explained its meaning and application to different grades of steel used in the machine shop and in the tool room. Various constitutents of steel such as ferrite, cementite, pearlite, etc., as well as impurities often encountered in steel, were shown on the screen. Their occurrence and influence on the physical properties of the steel was explained in such a manner that it could be clearly understood by anyone who comes in contact with the problems of handling and using steels.

Professor Homerberg also gave a thorough theoretical explanation of

what happens to steel when it is subjected to various heat treating processes, such as hardening, tempering, normalizing, spheroidizing, etc.

Perhaps the most interesting part of the talk was his theoretical interpretation of different cases which came to his personal attention when examining materials which failed in service, due to impurities. Generally, these materials had poor machining properties and were entirely unsuitable for the purpose for which they were intended.

He also explained how in many instances it was possible to improve the properties of steel and sometime save it from scrapping by suitable heat treatment.

The meeting was conducted by the newly elected chairman, Mr. Oliver of the Springfield Armory, and it was well attended, approximately sixty members and guests being present. *N. A. Glaskowsky.*

ST. LOUIS CHAPTER

The May meeting of the chapter took place at the American Annex Hotel on the 15th of the month. Mr. Rinehart of the American Rolling Mill Co., Middletown, Ohio, was the speaker of the evening, his subject being, "The Manufacture of Armco Ingot Iron." He described the process in a clear and entertaining way and demonstrated by a sensitive galvanometer the electrolitic action of positive and negative metals in a glass of water, which was very remarkable. The members and guests were then entertained with a motion picture, which illustrated most of the processes of the making of ingot iron from the blast furnace to the galvanized sheet. Preceding the program of the evening the following officers were elected: chairman, John B. Schuck; vice-chairman, R. M. Pease; secretary-treasurer, Alan Jackman.

Executive Committee: W. A. Mueller, I. R. Propes, F. J. Stoltz, F. W. Oches, J. J. Rammelsburg. *Alan Jackman.*

The regular June meeting of the St. Louis chapter of the American Society for Steel Treating was held at the American Annex Hotel, Friday, June 19, 1925. The speaker of the evening was Mr. Muir L. Frey, metallurgist of Peoria, Illinois. Mr. Frey's paper was well received. Mr. Frey dealt with "The Heat Treatment of Cast Iron." He described the various types of cast iron and semi-steel and their analyses; he showed clearly the increased strength from several heat treatments, and with the aid of lantern slides showed the different microstructures. Different heat treatments were suggested for various types of castings. He summed up his paper with these points:

1. Hard spots in cast iron castings due to combined carbon can be removed by heating to 1750 degrees Fahr.
2. There is a certain application for hardening and drawing cast iron.
3. Cast iron to which steel has been added has increased tensile strength.
4. Chilled iron can be softened, then rehardened by heat treatment.
5. White iron can be quickly graphitized by heating to 1750 degrees Fahr., then quenching and drawing.

A lively discussion followed, and Mr. Frey answered many questions.

Many other points in heat treating steel were broupht up and discussed by the members and much interest was shown. *Alan Jackman.*

TORONTO CHAPTER

At the annual general meeting of the chapter, the following were elected to hold office for the ensuing year: chairman, Prof. O. W. Ellis; vice-chairman, J. W. McBean.

The members of the executive committee as well as a secretary-treasurer will be elected later and will be reported at that time.

O. W. Ellis.

TRI-CITY CHAPTER

R. D. Malm, sales manager of the Lincoln Electric Co., of Cleveland, talked to the Tri-City chapter of the American Society for Steel Treating on Electric Welding at the Davenport Chamber of Commerce last night. Mr. Malm told of the progress welding had made in the past few years, stating that 90 per cent of all the tanks that are being made today are being welded instead of riveted. He also said that in most cases where welding had proven unsatisfactory this was caused by the operator not understanding the principals of expansion and contraction, and not making proper allowance for same. Also that operators, in welding from one side often reinforced the weld only on that side, thinking that they were making a stronger job, while in fact this causes strains in the metal, making a weaker job unless the weld is equally reinforced on both sides. Aluminum welding is also now being done very successfully by the electric process. Mr. Malm illustrated various welding jobs with blackboard sketches showing different methods used, to distribute the heat so as not to get up strains in the metal that would cause it to break afterward. Welders and men interested in welding from various large plants in the Quad-Cities and Rock Island Arsenal were present and showed much interest in the various problems that were discussed.

Election of officers also took place at this meeting. C. H. Burgston of the Deere & Co. was elected chairman, C. A. Schoessel of Deere-Harvester Co., vice chairman; Chas. F. Scherer of the Davenport Machine & Foundry Co., secretary-treasurer.

Mr. Burgston and Mr. Scherer were selected to represent the Tri-City chapter at the Annual Convention in Cleveland.

Arrangements were also made to hold the Tri-City chapter annual picnic in June.

WASHINGTON CHAPTER

The talk before the May meeting of the Washington chapter of the A. S. S. T. was given by A. W. F. Green, metallurgist, John Illingworth Steel Company, Philadelphia. Mr. Green chose as his subject "The Manufacture of Carbon Tool Steels."

After first reviewing the historical side of the development of the crucible process for the manufacture of steel, the speaker entered into a detailed consideration of the various steps in the production of carbon steels of 0.30 to 1.50 per cent carbon. The furnace equipment and the melting process were first

considered and then in succession, the aging, annealing, hammering and rolling operations rquired in the preparation of the highest grades of product. Mr. Green laid particular emphasis upon the desirability of aging unannealed carbon steel ingots as being a means of effectively removing scale in the early hammering or rolling processes, thereby yielding a product free from the usual surface defects. A similar effect is the aid to scale removal of alternate oval and square passes in the rolling mill.

Photomicrographs were shown of steels varying over the carbon range indicated above in the "as cast" condtion, after annealing, after hammering, after rolling and after final annealing treatments of various types.

Consideration was also given to the occurrence and causes of such defects as pipe, segregation, laps, cracks, seams, decarburization, etc. In considerng the applications of carbon tool steels, Mr. Green remarked that many carbon steels which have been shown to have spongy centers when examined by the hot acid etch proved to be ideally suited for drawing dies in which the working surface was presumably in the spongy area. He also stated that many heading dies made from carbon steels of approxmately 1.10 per cent carbon gave better service when hardened from 1600 degrees Fahr. and tempered at 600 degrees Fahr. than after any other heat treatment that had been employed.

An extended discussion followed Mr. Green's paper, in which many of the chapter members took part. Among the features given attention were the warping of tools as affected by previous heat treatment of the steel, the hardness of carbon tool steels resultant from different annealing and hardening treatments, and the variables of the steel making process that affected the "quality" of the steels and the results obtained from their use.

W. H. White.

WORCESTER CHAPTER

The Worcester chapter's last meeting of the season was held at the University Club, May 26th, a steak supper being served at 6:30 p. m.

Mr. Porter, the retiring chairman, announced the names of the officers just elected for the season 1925-26. He then called on the old officers and committee chairmen for a few words regarding their work during the past year and what progress had been made.

H. H. Harris of the General Alloys Co. was then presented as the speaker. His subject was, "Heat Resisting Alloys and Carburizing Containers."

Mr. Harris said that expense of renewal due to the scaling and warping of cast iron carburizing boxes, as well as their excessive thickness and consequent weight which must all be heated, made pack carburizing an expensive process.

He justified the use of alloy containers not only from the standpoint of less cost per hour under heat, but by the saving in fuel and time required, the thin walled alloy container transferring heat to the contents much quicker than the heavy iron container, also having much less weight itself to be heated.

Mr. Harris stated that it was not difficult to combine the necessary metals in a melting pot to make a good alloy, but that the main difficulty was in

making the casting. He said that the main reasons for failure of alloy boxes were oxidation and fatigue, failure from the second cause being due to alternate expansion and contraction; irregular shaped castings being much more subject to failure from this cause.

The speaker divided heat resisting alloys into two classes; those having 50 per cent or over of iron in their composition and those having a much smaller per cent.

He pointed out several cases where heat resisting alloys containing a high percentage of iron have been withdrawn from the market and said that in general those having a high percentage of iron had proven unsatisfactory.

On the other hand, he said, alloys of low iron content are at present produced on a large scale and have given a fair degree of satisfaction. In regard to the chemical composition Mr. Harris said that nickel formed the base for most heat resisting alloys, metallic chromium being another ingredient. He also said that up to one-half of 1 per cent of aluminum had been successfully used.

With regard to the guarantee usually given with alloy boxes the speaker said that he wished to clear up a general misunderstanding that seems to exist. The guarantee is not to be confused with the life of the box or container, it being the usual case for a container to exceed the guarantee by a considerable margin. As the alloy manufacturer has no control over the operating conditions in the plant where his product is used, the guarantee must necessarily be conservative.

Mr. Harris pointed out that the selling price of an alloy depends on the cost of manufacture and that, in the case of alloys as in most everything else in life, you get about what you pay for.

A number of slides were shown illustrating the design of alloy boxes as contrasted with the old style cast iron containers, also a number of inverted boxes, which design is becoming popular. Mr. Harris said that luting of alloy boxes with clay when preparing them for the furnace was an unnecessary expense.

Attendance at the supper was forty-one, and quite a few others came later to hear Mr. Harris' talk. *R. J. Phelon.*

Report of Executive Committee Meeting of Worcester Chapter A. S. S. T.
Held Wednesday, June 11, 1925

The new officers and executive committee are as follows: Chairman, W. C. Searle; vice-chairman, L. D. Granger; secretary-treasurer, E. D. Clark.

Executive Committee: Luther Holt, J. A. Kelly, Roland Cook, P. A. Porter, R. J. Phelon.

Those present were: Messrs. Searle, Granger, Porter, Holt, Kelly, Phelon. Those absent: Cook, Clark.

Mr. Granger is to have charge of the program for this year, but a start has been made by Mr. Searle who has arranged for Mr. d'Arcambal to speak at the first meeting. Mr. Bidle and Mr. Eisenman will be here for our second meeting and Dr. Langenburg will speak at the third meeting.

It was suggested that we might use the tickets sold for the supper served

with each meeting as a registration blank and that a quantity of tickets might be printed, providing a space for the registration at the bottom of the ticket. These tickets could be completed as occasion demanded for the particular meeting at which they were to be used.

Mr. Phelon was appointed as an "On to Cleveland Committee." Mr. Porter is to take care of publicity this year.

The matter of a combination of all the local Engineering societies was brought up, and Mr. Searle is to try and obtain a copy of the report made by the committee which investigated this matter some time ago.

It was decided to hold the meetings at the University Club when possible and Mr. Granger has offered the use of their Wickwire-Spencer Corp. lunch room at Webster Square.

No one was assigned to look after membership at this meeting.

R. J. Phelon.

L. Dwight Granger who spoke to the Worcester chapter on April 16th has called attention to an error in the report of his talk which appeared in the May issue of TRANSACTIONS. Referring to the size of the spring casing in the phonograph referred to by him, it was necessary to increase the size of this spring case from about 3 inches in diameter to approximately 4 inches instead of from 6 to 12 inches as stated in the report.

R. J. Phelon.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member; and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

(As of May 25, 1925)

ALLEGHENY STEEL COMPANY, (S-6), Brackenridge, Pa.

ALLINGTON, A. L., (M-4), chemist, Studebaker Corp., Detroit.

ALUMBAUGH, W. C., (M-2), assistant foreman, heat treating, Oakland Motor Co.; *mail* 268 Raeburn Court, Pontiac, Mich.

ANDERSON, H. M., (M-5), pyrometer man, Hudson Motor Car Co., Detroit; *mail* 728 St. Clair Ave., Grosse Pointe, Mich.

ANDERSON, R. O., (Jr-5), student, Carnegie Institute of Technology, Pittsburgh.

ARMSTRONG, L. K., (S-5), manager's assistant, Fales & Jenks Machine Co., Pawtucket, R. I.

ARTHUR, J. E., (M-4), superintendent, melting department, Union Electric Steel Co., Carnegie, Pa.

AUSTIN, H. S., (M-4), chief chemist and metallurgist, Campbell, Wyant and Cannon Foundry Co., Muskegon, Mich.; *mail* 728 Peck St., Muskegon Heights, Mich.

BARDES, D. L., (A-4), salesman, Vanadium Alloys Steel Co.; *mail* 1602 Oak Grove Ave., Swissvale, Pa.

BECK, W. J., (M-6), director of research, American Rolling Mill Co.; *mail* 401 The Alameda, Middletown, Ohio.

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(Continued on Page 36 Adv. Sec.)

Items of Interest

FRED H. BULTMAN, machinery manufacturer of Cleveland, died at his home in Long Beach, Calif., June 6, at the age of 87 years. Mr. Bultman emigrated from Germany to Cleveland in 1880. Thirteen years later he founded the F. H. Bultman Company and remained actively engaged in the business until about 1915. Shortly after his retirement he moved to California.

The General Electric Co., Schenectady, N. Y., has published a bulletin Y-1866, listing representative installations of electrical heating equipment. Each application is listed separately. Additional information includes the name of the company using the installation, the process, size of apparatus, type of equipment and power rating. Many of the installations are for treating iron and steel and non-ferrous metals.

The Wilson-Maeulen Co., Inc., New York, have recently issued a bulletin entitled, "Electric Thermometers," which is well illustrated, giving descriptions of the instruments and price list.

A bulletin entitled, "Shepard Equipment for the Iron and Steel Industry," has been published by the Shepard Electric Crane & Hoist Co., of Montour Falls, N. Y. This book gives the application of electric cranes and hoists in the iron and steel industry. Each machine, described and illustrated, is a standard product of the company. The explanation and description is so arranged as to give the iron and steel man a clear conception of the types of machines offered by the company. A general description of each machine is given as well as a close-up view and an actual installation view.

The Bristol Co., Waterbury, Conn., announce the publication of their catalog No. 1303—Bristol's Gas Filled Recording Thermometers. This is widely illustrated, giving description, and price list.

W. B. McSkimmon has been elected president of the Union Twist Drill Co., Athol, Mass., owner of the S. W. Card Manufacturing Co., Mansfield, Ohio, and of the Butterfield Tap Die Co., Derby Line, Vt., and Rock Island, Canada. Through his untiring efforts Mr. McSkimmon has held the positions of treasurer of the S. W. Card Company and secretary of the Union Twist Drill Company; vice-president and general manager of the Union Twist Drill Company and its subsidiaries, and now is at the head of the organization.

George J. Hagan, 1105 People's Bank Building, Pittsburgh, who recently disposed of his interests in the George J. Hagan Company, and now is conducting a general furnace business, has been appointed representative for the Chicago Flexible Shaft Company, covering its line of industrial furnaces. These furnaces range from a small solder iron heater to the car-type annealing

Let's Go!

A. S. S. T. Annual Convention
National Steel Exposition

PUBLIC AUDITORIUM
CLEVELAND

September 14 - 18

43,000 executives, production managers, buyers and scientists attended last year's Exposition in Boston. This year every available foot of exposition space in the great Cleveland Public Auditorium has been reserved and other exhibitors are anxious to get in.

The technical program will again be of "superior merit," including symposiums on metallurgical education, hardness testing and in addition a technical session on the manufacture of steel.

The S. A. E. Production Meeting will be held in Cleveland the same week, while the A. S. M. E. will contribute a session on machine shop practice.

The exhibit will be larger than at Boston. 200 manufacturers will have their products on display and *in operation*. Everyone in your plant from the president down should plan to spend that week in Cleveland.

REDUCED RAILROAD RATES

Certificates entitling members of the A. S. S. T. and their families to fare and one-half for the round trip will be mailed in due time. See folder mailed with data sheets for further details, or call on the chairman of your local "On To Cleveland" committee.

Join the crowd to Cleveland September 14 to 18!

AMERICAN SOCIETY *for* STEEL TREATING

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furnace and porcelain enameling furnace. Mr. Hagan will continue also his own line of industrial furnaces.

Heman Ely, vice-president and treasurer of the Timken Roller Bearing Co., Canton, Ohio, has retired from active connection with the company. Mr. Ely made his connection with the company in 1916 and was appointed treasurer. He became vice-president and treasurer in 1920. Mr. Ely has announced no plans for future connections. H. J. Porter, general sales manager of the Timken company, has been advanced to vice-president in charge of sales. L. M. Klinedinst, assistant to Mr. Porter, becomes general sales manager of the industrial division.

H. A. Baxter has resigned as vice-president in charge of sales of the Tacony Steel Company and as general manager of sales of the Penn Seaboard Steel Corp., Philadelphia. W. C. Prendergast, formerly sales agent of these companies in the New York territory, has succeeded Mr. Baxter, with headquarters in Philadelphia.

Frank Garrett, formerly with the Firth-Sterling Steel Co., McKeesport, Pa., and lately with the Latrobe Electric Steel Co., Latrobe, Pa., recently has become affiliated with the Universal Steel Co., Bridgeville, Pa., in the capacity of research metallurgist. Mr. Garrett is a graduate of Lehigh university.

George A. Drysdale has resigned as metallurgical editor of the *Foundry* to become associated with the Metal Improvement Co., Cleveland, on June 1, as metallurgical engineer.

G. A. Richardson of the Bethlehem Steel Corporation has been giving a series of lectures, illustrated by moving pictures, on the processes of making steel from the ore to the finished product. He spoke in Portland, Ore., on April 20-21 and in Seattle, Wash., on April 23-24. He has also delivered the lecture in other large Pacific Coast cities.

C. H. Martin now is the district representative in Wisconsin and Illinois for Holcroft & Co., Detroit. Mr. Martin took up his new duties May 1, having previously been with the People's Gas, Light & Coke Co., Chicago. His headquarters will be in Chicago. Holcroft & Co. are contracting engineers for open-hearth furnaces, annealing furnaces, core ovens, and other furnaces.

P. A. E. Armstrong, who resigned May 12 from the Ludlum Steel Co., Watervliet, N. Y., for the past eight years, has been identified prominently with the development of rustless and alloy steel. Mr. Armstrong was vice-president, general sales manager and a director of the Ludlum Steel Co. When he joined the Ludlum company it manufactured plain carbon steel and high speed steel. During his connection with it he developed and patented a large number of high grade alloy steels which since have been accepted widely. One of his alloy developments applied to valves has made possible high alti-

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EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

HEAT TREATING FOREMAN desires position. Thoroughly experienced with executive experience and complete knowledge of all steels. Address 6-1.

EXPERIENCED HARDENER desires position. Has had full supervision over hardening, sand blasting, carburizing, Hump method of hardening gears, cyanide hardening, lead pot, salt pot, barium and salt petre and oil drawing work. Also has had two years' experience at pyrometer checking and installing. Semi-muffle furnace and production hardening of all kinds. Address 6-10.

GRADUATE MECHANICAL ENGINEER desires position as assistant superintendent or engineer of tests. Age 38. Fourteen years' experience in production, heat treatment, inspection and fabrication of steels. Have successfully handled carbon, alloy and high speed bar steels and served as assistant metallurgist, metallographer and heat treater. Address 6-15.

CHEMIST with 8 and one-half years' experience in steel works laboratory on miscellaneous work desires position. Address 7-5.

METALLURGIST of 16 years' experience in development work and investigations in alloy steels desires position. Some few years' training in sales and sales promotion. Available at once. Would be interested in either sales work or laboratory executive. Address 7-10.

METALLURGIST AND HEAT TREATER desirous of changing positions. Has had 7 years' practical experience as a hardener and at present time, supervisor of heat treating department. Has thorough knowledge of metallography, also experience in performing analysis in non-ferrous and ferrous alloys. Remuneration nominal, and best of references. Address 7-25.

RECENT GRADUATE OF METALLURGY desires position. Graduate of Case School of Applied Science (1925). Has had training in metallography. Can furnish excellent references. Cleveland district preferred. Address 7-30.

POSITIONS WANTED

GRADUATE ENGINEER, Tech. '24, one year university teaching experience, desires connection with firm or laboratory in metallography, heat-treatment or testing materials. Graduated in mechanical engineering but took special courses along above lines. Experienced in laboratory methods. Can talk and write French and German. Address 7-35.

POSITIONS OPEN

EXPERIENCED HARDENER with a thorough knowledge of the heat treatment of high speed, carbon, alloy steels and carbonizing. Position assistant to foreman and applicant should be capable of taking charge. In answer, detail experience, age, married or single and state salary expected. Address 6-20.

WANTED—In Chicago, man experienced in metallurgy and heat treatment of dies. Address 7-20.

FOR SALE

FOR SALE: 50-Ton Tinius Olsen Belt Driven Testing Machine with full equipment for steel test bars. Practically new. Price very reasonable. Address Bay State Machinery Co., 54 Old Colony Ave., South Boston, Mass.

FOR SALE—Three SHORE SCLEROSCOPES. With stands; in very good condition. Price $115.00 each. Address 6-5.

HEAT TREATING EQUIPMENT FOR SALE: Two No. 150 Bellevue Furnaces. Brand new. Never used. Low price for immediate sale. Address Curtiss Aeroplane & Motor Co., Inc., Buffalo, N. Y.

WANTED—One No. 2 Carbonizing machine, American Gas Furnace Company. Must be in good condition. Address 7-15.

tude and long jump aeronautic flights. He developed rustless steel from cutlery use to wide engineering application. Mr. Armstrong organized and developed the sales department and methods of distribution for the Ludlum company. His contributions to conventions and technical publications on rustless irons and steels have been recognized widely. Mr. Armstrong will take an extended vacation before returning to activity in the iron and steel industry.

R. P. Smith, formerly of Detroit, has accepted a position with the Eaton Axle and Spring Company as factory manager of their Axle Plant at 140th Street, Cleveland.

G. S. McFarland, member of the A. S. S. T., formerly metallurgist, Jeffrey Manufacturing Company of Columbus, has now entered the field of consulting metallurgical engineering work with headquarters in Columbus.

The Combustion Utilities Corporation announce the removal of their executive offices from 8-10 Bridge Street to 60 Wall Street, New York City.

Nugent Steel Castings Company of Chicago, manufacturers of small and thin section steel castings, have recently placed in operation an electric annealing furnace for the treatment, in this manner, of their entire product. The installation is unique, in that it embodies features of design, also of heat application that have not hitherto been attempted in the heat treatment of steel castings. The company specializes in the manufacture of high grade electric steel castings.

Colonial Steel Company announce the removal from their temporary location in the Drexel Building to their new office and warehouse at 308 North 15th Street, Philadelphia. J. A. Succop is district manager in charge of this office.

H. H. Davis, formerly in Springfield, Mass., is now with Production Materials, Ltd., which is the Canadian subsidiary of the E. F. Houghton Company of Philadelphia. Mr. Davis is Canadian representative for the company.

W. B. Byers, treasurer, A. E. Hunt Steel Company, Boston, passed away suddenly on May 6th. He was closely associated with T. L. Kirkpatrick, vice-president of the company and a member of the A. S. S. T.

Republic Flow Meters Company of Chicago announce that they have opened a factory branch office in Buffalo, N. Y., the address being 535 Bramson Building. This office will be in charge of W. W. Barron, formerly of the Chicago office. They say that their business has expanded so rapidly in the Buffalo territory that they found it impossible to give their customers

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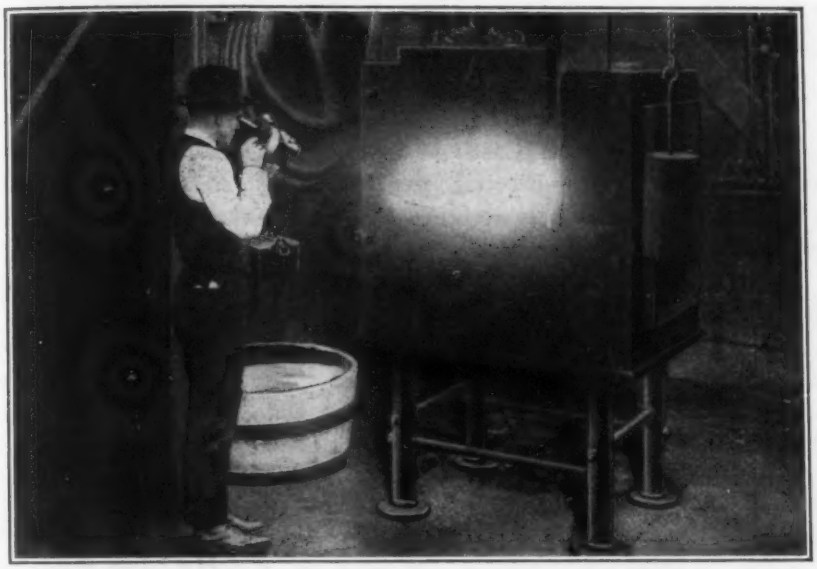
THE F. & F. OPTICAL PYROMETER

(Fisher & Foote)

A Direct Reading Optical Pyrometer for Measuring Temperatures from 1,600° to 4,000° F.

ACCURATE — SIMPLE — RUGGED



(In observing heat treating temperatures with the F. & F. Optical Pyrometer the temperature of the object itself is measured and not that of the furnace.)

Advantages of the F. & F. Optical Pyrometer

1. The temperature is read directly from the instrument without referring to any tables.
2. Small objects can be observed.
3. The temperature of molten materials and heated objects may be measured in all stages of operation: such as in the furnace, pouring, rolling, heat treating, forging, etc.
4. Readings are not dependent upon delicate electrical measuring instruments.
5. Lamp burns at low temperature, has a long life and can be replaced for $5.00.
6. There is no deterioration; the pyrometer does not come in contact with the heated object, nor is there any delay incident to heating any portion of the instrument.

Price, complete — $175.00

Designed and Manufactured by

SCIENTIFIC MATERIALS COMPANY

"Everything for the Laboratory"

PITTSBURGH, PA.

and prospects sufficient personal service. Mr. Barron is an engineer with many years' experience in the power plant field and will be glad to give assistance or information concerning problems in the field of fluid measurement of power control.

J. H. Wilson, formerly with the United Alloy Steel Corp., Canton, Ohio, has been appointed works manager of the Pacific Sheet Steel Corp., in South San Francisco. Mr. Wilson expects to take charge, including the operation of the mill on August 15th.

It has been announced that Charles N. Ring, until recently works manager of the Allied Steel Castings Co., Harvey, Ill., has been appointed as assistant director of the Electric Steel Founders' Research Group, succeeding W. J. Corbett, who recently resigned to become secretary-manager of the Steel Founders' Society of America.

Mr. Ring has had more than 15 years' experience in steel casting manufacture, following his education at Washington University and the University of Missouri. At various times Mr. Ring was connected with the American Steel Foundries, the Commonwealth Steel Company, the Illinois Steel Company, the Laclede Steel Company, and the Ohio Steel Foundry, prior to his connection with the Allied Steel Castings Company.

The director of the Electric Steel Founders' Research Group is R. A. Bull, and the companies of which the Group is composed are: Fort Pitt Steel Castings Co., McKeesport, Pa.; Lebanon Steel Foundry, Lebanon, Pa.; Michigan Steel Castings Co., Detroit; Nugent Steel Castings Co., Chicago; and Sivyer Steel Castings Co., Milwaukee.

Albert E. White, professor of metallurgical engineering and director of the department of engineering research of the University of Michigan, and past president of the American Society for Steel Treating, recently received the honorary degree of doctor of science from Brown University, in recognition of his contributions to the science of metallurgy.

NEW MEMBERS

(Concluded from Page 133)

WALDECK, R., (Jr-5), student, Case School of Applied Science, Cleveland; *mail* R. F. D. No. 3, Willoughby, Ohio.

WARE, B. J., (M-6), superintendent, McQuay Morris Mfg. Co.; *mail* 130 West 7th St., Connersville, Ind.

WILSON, A. B., (M-6), metallurgist, Flint Plant, Chevrolet Motor Co., Flint, Mich.

WISE, R. T., (M-6), manager, Standard Die and Specialty Co., Berkeley, Calif.

WOOD, T., (M-6), foreman, heat treat department, Chevrolet Motor Car Co.; Flint, Mich.

YOUNGER, J., (M-6), editor-publisher, Automotive Abstracts; *mail* 2010 East 102nd St., Cleveland.